HACCP and ISO 22000

Application to Foods of Animal Origin

HACCP and ISO 22000: Application to Foods of Animal Origin
Edited by Ioannis S. Arvanitoyannis
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Dedicated to

my beloved wife Nicole for her continuous and unfailing support throughout the long preparation of this book

and

my children Iason, Artemis-Eleni and Nefeli-Kallisti, whose presence has lightened and warmed our lives.

Ioannis S. Arvanitoyannis

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Preface

Numerous food crises have occurred globally in recent years, originating in both primary agricultural production and in the food manufacturing industries. Cases have included:

the outbreak of 'mad cow disease'
the presence of dioxins in animal feed
the use of the dye Sudan Red I
the presence of acrylamide in various fried/baked foods
the presence of pesticides, nitrates, dioxins, furans in foods and mislabelled or unlabelled genetically modified foods

Both governments and consumers lost confidence that applied quality (ISO 9001:2000) and safety (HACCP) control systems were being effectively operated. In view of the fact that the previously applied HACCP system did not manage to solve all food safety and quality-related problems (mainly due to chemical and microbiological hazards), another system, ISO 22000: 2005, quality and safety, was put forward which is anticipated to improve the situation.

This book aims at addressing a current gap in the food safety field by providing a number of examples illustrating the application of ISO 22000 to products of animal origin. The book includes nine chapters bearing the following titles: (1) HACCP and ISO 22000 – a comparison of the two systems, (2) A summary of EU, US and Canadian legislation relating to safety in foods of animal origin, (3) Dairy foods, (4) Meat and meat products, (5) Poultry, (6) Eggs, (7) Seafood, (8) Catering and (9) Conclusions and future directions.

Several examples per food category are provided and numerous references are cited (more than 1600).

It is anticipated that this book will be a useful tool for undergraduate and postgraduate students, university professors, researchers, consultants and industrialists who would like to have access to applied examples of ISO 22000 and how it differs from HACCP.

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Abbreviations

ADI	Acceptable dairy intake
AEA	Association of European Airlines
AFB1	Aflatoxin B1
AFLP	Amplified fragment length polymorphism
AFM1	Aflatoxin M1
AHS	African horse sickness
ALARA	As low as reasonably achievable
ALOP	Appropriate level of protection
AMI	American Meat Institute
APC	Aerobic plate count
APMV-1	Avian paramyxovirus serotype-1
AR	Antimicrobial resistant
ASF	African swine fever
ATP	Adenosine triphosphate
AVC	Aerobic viable count
BHT	Butylated hydroxytoluene
BMPs	Best management practices
BSE	Bovine spongiform encephalopathy
BVD	Bovine viral diarrhoea
CBI	Computer-based instructions
CCPs	Critical control points
CFIA	Canadian Food Inspection Agency
cfu	Colony forming unit
CP	Commercial plant
CPs	Control points
CPU	Central processing unit
CSF	Classical swine fever
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DEFT	Direct epifluorescent filter technique
DIS	Draft International Standard
DM	Dry matter
DSI	Direct sample introduction
DSP	Diarrhetic shellfish poisoning
EAN	European article number
EBL	Enzootic bovine leucosis
E. coli	*Escherichia coli*
EDP	Experimental dairy plant
EHEC	Enterohaemorrhagic *E. coli*
EHS	Environmental health specialist
EL	Extruded linseed
ELISA	Enzyme-linked immunosorbent assay
EMAR	Eco-Management and Audit Regulation
EO	Electrolysed oxidising
EPA	Environmental Protection Agency
EU	European Union
FAO	Food and Agriculture Organization
FDA	Food and Drug Administration
FFQ	Food frequency questionnaire
FIFO	First in first out
FMD	Foot-and-mouth disease
FMEA	Failure, mode and effect analysis
FMI	Food Marketing Institute
FMM	Food MicroModel
FPLC	Fast protein liquid chromatography
FSMS	Food safety management system
FSO	Food safety objectives
GAP	Good agriculture practice
GATT	General Agreement on Tariffs and Trade
GC	Gas chromatography
GFP	Good farming practice
GHA	Green Health Authorities
GHCP	Good hygiene control point
GHP	Good hygiene practice
GL	Ground linseed
GLC	Gas–liquid chromatography
GMDP	Good manufacturing and distribution practice
GMOs	Genetically modified organisms
GMP	Good manufacturing practice

GRAS	Generally recognised as safe
GTX	Gliotoxin
HACCP	Hazard analysis critical control point
HAH	Halogenated aromatic hydrocarbons
HCP	Hygienic control point
HDPE	High-density polyethylene
HFP	Histamine fish poisoning
HHP	High hydrostatic pressure
HIMP	HACCP-based inspection model project
HMM LPS	High-molecular-mass lipopolysaccharide
HP	High pressure
HRAs	Halogen-releasing agents
HTST	High-temperature short time
HUS	Haemolytic uraemic syndrome
IARC	International Agency for Research on Cancer
ICMSF	International Commission on Microbiological Specifications for Foods
IDF	Internal Dairy Federation
IEF	Isoelectric focusing
IgC	Immunoglobulin C
IID	Infectious intestinal disease
IMF	Instant milk formula
IT	Information theory
JD	Johne's disease
LAB	Lactic acid bacteria
Lb	Lactobacilli
LCA	Life cycle analysis/assessment
LDA	Linear discriminant analysis
LEW	Liquid egg white
LEY	Liquid egg yolk
LIFO	Last in first out
LISA	Longitudinally integrated safety assurance
Ln	*Leuconostoc*
LPS	Lipopolysaccharide
LSL	Long shelf life
MAP	Modified atmosphere packaging
MBR	Methylene blue reduction
MDM	Mechanically deboned turkey meat
MF	Microfiltration
MILP	Mixed-integer linear programming
MIR	Minimal infectious range
MMT	Million metric tonnes
MP	Minimally processed
MPC	Milk protein concentrate
MPN	Most probable number
MR	Multi-resistant
MRA	Microbiological risk assessment
MRL	Maximum residue limit
MRM	Mechanically removed meat
MSRV	Modified semi-solid Rappaport–Vassiliadis
MUG	Methylumbelliferyl-b-glucuronide
NACMCF	National Advisory Committee on Microbiological Criteria for Foods
NASA	National Aeronautics and Space Administration
ND	Newcastle disease
NDV	Newcastle disease virus
NF	Nanofiltration
NFDM	Non-fat dried milk
NIR	Near-infrared
NIRS	Near-infrared reflectance spectroscopy
NOAEL	No-observed-adverse-effect level
NOP	National Organization of Pharmaceuticals
NRA	National Restaurant Association
NRTE	Non-ready to eat
NSLAB	Non-starter lactic acid bacteria
NTMS	Non-traditional meat starter
OCDD	1,2,3,4,5,6,7,8,9-Octachlorodibenzo-p-dioxin
OCPs	Organochlorinated pesticides
OIE	Office International-Epizooties
OR	Odds ratio
PAGE	Parametric analysis of gene set enrichment
PAHs	Polycyclic aromatic hydrocarbons
PCBs	Polychlorinated biphenyls
PCDF	Polychlorinated dibenzofurans
PET	Polyethylene terephthalate
PFGE	Pulsed-field gel electrophoresis
PFMEA	Production failure mode and effect analysis
PP	Polypropylene
p,p-DDE	Dichlorodiphenyldichloroethylene
PPR	Peste des petits ruminants
PRM	Process risk model
PRP	Prerequisite programme
PS	Polystyrene
PUFA	Polyunsaturated fatty acids
QA	Quality assurance
QACs	Quaternary ammonium compounds
QCM	Quality control methodology
QRA	Quantitative risk assessment
RASFF	Rapid Alert System for Food and Feed
RFID	Radio-frequency identification
RLU	Relative light unit
RO	Reverse osmosis

RP-HPLC	Reversed phase high-performance liquid chromatography
RPN	Risk priority number
RTE	Ready to eat
RTU	Ready to use
SCAP	Self-care action programme
SCM	Standard cultural method
SE	*Salmonella enteritidis*
SMEs	Small- and medium-sized enterprises
SOP	Standard operating procedure
SPC	Statistical process control
SPF	Specific pathogen-free
SPR	Surface plasmon resonance
SPS	Sanitary and phytosanitary
SSOP	Sanitation standard operation procedure
Str	Streptococcus
SVD	Swine vesicular disease
TBARS	Thiobarbituric acid-reactive substance
TBT	Technical barriers to trade
TEQ	Toxic equivalent quantity
TGI	Tierges and Heits Index
TLC	Thin liquid chromatography
TPC	Total plate count
TSE	Transmissible spongiform encephalopathy
TTI	Time–temperature indicators
TVBN	Total volatile basic nitrogen
TVC	Total viable count
UCFM	Uncooked comminuted fermented meat
UF	Ultrafiltration
UHT	Ultra-high temperature
USDA	United States Department of Agriculture
VEE	Viral equine encephalomyelitis
VS	Vesicular stomatitis
VSP	Very small plant
VT1	Verotoxin 1
VT2	Verotoxin 2
VTEC	Verocytotoxin-producing *Escherichia coli*
WOF	Warmed over flavour
WPC	Whey protein concentrate
WTO	World Trade Organization

Part I
Introduction

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HACCP and ISO 22000 – A Comparison of the Two Systems

Ioannis S. Arvanitoyannis and Aikaterini Kassaveti

1.1 HACCP

1.1.1 Introduction to HACCP

Food safety in the early twenty-first century is an international challenge requiring close cooperation between countries in agreeing standards and in setting up transnational surveillance systems. The lessons of the past two decades are plain to those engaged in the food industry. No longer can farmers grow just what they want or use technical aids to farming without taking into account the effect on the quality of the food produced (Rooney and Wall, 2003). The behaviour of European consumers has been gradually changing. They currently require not only much higher dietary quality, hygiene and health standards in the products they purchase, but they also look for certification and reassurance of products' origins (national or geographical) and production methods. This heightened consumer awareness is reflected in the demand for products endowed with individual characteristics due to specific production methods, composition or origin (national or geographic; Anon, 2004).

No matter how professional and effective a company may be, there is always the possibility of a serious problem arising which is unforeseen or eventually develops into a major crisis. However, thinking through the possible ramifications of such an eventuality and preparing responses and scenarios to deal with it, always ensures that an organisation is better prepared for the unexpected (Doeg, 1995). The Hazard Analysis and Critical Control Point (HACCP) system is a science-based system created to identify specific hazards and actions to control them in order to ensure food safety and quality. It can be considered an efficient tool for both the food industry and health authorities in preventing foodborne diseases (Vela and Fernandez, 2003). A 'hazard' is 'a biological, chemical or physical agent in, or condition of, food with the potential to cause an adverse health effect' (Codex Alimentarius, 1997). A HACCP system should be developed for every food production line and adapted for the individual products and processes (da Cruz *et al.*, 2006). HACCP systems have become mandatory for food industry in the European Union (European Community Directive, 1993).

'Food complaints fall into 7 broad categories within which there are a number of possible subcategories':

1. A complaint from a consumer
   (a) Food complaints fall into four broad categories:
      (i) foreign objects found in food or food not meeting the consumers' expectations
      (ii) poor food premises conditions
      (iii) poor food handling practices, or
      (iv) alleged cases of food poisoning (www.campaspe.vic.gov.au/hardcopy/111314_186479.pdf).
2. A complaint from the regulatory authorities
   (a) Often instigated by a complaint from consumers and falling into the same broad sub-categories as given above
   (b) As a result of routine monitoring and premise visits
   (c) As a result of investigations into events such as outbreaks of 'food poisoning'
3. A phone call from the police
   (a) For example, warning of
      (i) an incidence of food poisoning in the area
      (ii) detection of 'food fraud'
      (iii) malicious action or intended action against the company or its products.
4. A threatening message direct to the company as per 3 (iii) above

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5. An enquiry from the media
6. The knock-on effect of a problem in another country
7. An industry issue, such as the use of an ingredient (Doeg, 1995).

To be effective, a food safety management system (FSMS) as exemplified by HACCP and mandatory under 2001/471/EC requires monitoring and control (of critical limits) of those process stages deemed critical to food safety. These process stages, identified as critical control points (CCPs), should be monitored and all non-compliances immediately corrected by removing the offending material, by re-skilling staff and by rectifying identified process or equipment faults (Ryan, 2007). HACCP procedures should be documented at all times. Record keeping is essential for providing documentation to the HACCP system and to verify the proper functioning of the system. Documentation and record keeping examples are given in Codex Alimentarius (2001).

Consumer awareness of the benefits that the HACCP approach provides is absolutely essential for effective implementation of HACCP programmes. What should be avoided is a consumer's misconception that HACCP represents only an extension of industry self-certification programmes without food authority control over the process (Kvenberg, 1998). HACCP systems are often seen as unnecessary, burdensome and bureaucratic in the food industry. They are often ineffective because the premise of the system is not emphasised. HACCP was intended to be 'a minimalist system that ensures maximum control'. It is important that employees understand its many benefits, including reduced waste and downtime. The system can become overly complicated due to a lack of internal knowledge of microbiological and toxicological issues, forcing those involved to seek advice from outside sources (Mortimore, 2003). A study revealed that in companies with less than 50 employees, HACCP implementation decreased proportionally as the number of employees decreased (Panisello *et al.*, 1999). An analysis of the barriers to HACCP implementation which include availability of appropriate training in HACCP methodology, access to technical expertise and the required resources (infrastructure and personnel) is available. The burden that this places on the small business are documentation, validation and verification (Taylor, 2001).

1.1.2 History of HACCP – outbreaks

The acronym HACCP is one which evokes 'food safety'. Originally developed to ensure microbiological safety of foodstuffs, HACCP has been broadened to include chemical and physical hazards in foods. The recent growing worldwide concern about food safety amongst public health authorities, consumers and other concerned parties, fuelled by the continuous reports of foodborne 'disease' outbreaks have been a major impetus in the introduction and widespread application of the HACCP system (http://www.unido.org/userfiles/cracknej/fgfs1.pdf). HACCP is merely a tool and is not designed to be a stand-alone programme. To be effective, other tools should include adherence to good manufacturing practices (GMPs), use of standard sanitation operating procedures and personal hygiene programmes (Rushing and Ward, 1999).

The HACCP system for managing food safety concerns grew from two major developments. The first breakthrough was associated with W.E. Deming, whose theories of quality management are widely regarded as a major factor in turning around the quality of Japanese products in the 1950s. Dr Deming and others developed Total Quality Management (TQM) systems, which emphasised a total systems approach to manufacturing that could improve quality while lowering costs (FAO, 1998). The second breakthrough was the HACCP proposal by the Pillsbury Company, NASA and the US Army laboratories. This was based on the failure, mode and effect analysis (FMEA) as used by engineers in construction designs. The HACCP concept was introduced in the United States in 1971 at the Conference of Food Protection where it was 'recommended for widespread use' (Bauman, 1974; FDA, 1972). The call for change was galvanised in the early 1990s with a tragic outbreak of *Escherichia coli* O157:H7 foodborne illness in the Northwest of the United States. Four children died and hundreds of people were taken ill in this outbreak, which resulted from the consumption of undercooked, contaminated ground beef. Food Safety and Inspection Services (FSIS) developed the regulatory proposal that became the Pathogen Reduction/HACCP Systems Rule (published as a final rule in 1996; Hulebak and Schlosser, 2002). Subsequently, as a means of safe food production, HACCP principles were adopted worldwide as given in Codex Alimentarius Commission (1997) and the National Advisory Committee on Microbiological Criteria for foods (NACMCF, 1992). HACCP became a mandatory programme for approximately 4000 seafood processors in December 1997 and also for foreign processors that ship seafood to the United States (FDA, 2001). The following month, in January 1998, the USDA's Food Safety and Inspection Service (FSIS) began implementing HACCP in the meat and poultry industry, starting with the largest

Table 1.1 Overview of HACCP systems.

Date	Highlights of HACCP
1959	The Pillsbury Company develops concept for NASA
1971	US national conference on food protection (1st mention of HACCP)
1972	The Pillsbury Company in the United States began the application of its HACCP concept to the manufacture of its consumer food products
1973	The Pillsbury Company published the first HACCP text in '*Food Safety Through the Hazard Analysis and Critical Control Point System*'
1980	WHO/ICMSF report on HACCP
1983	WHO Europe recommends HACCP
1985	National Academy of Science report on HACCP
1988	Formation of the National Advisory Committee on Microbiological Criteria for Foods (NACMCF)
1989	National Advisory Committee of Microbiological Specification for Food document endorsing HACCP approach
1990	Richmond Report advocated use of HACCP
1991	Codex HACCP draft
1992	The NACMCF system defined HACCP as 'a systematic approach to be used in food production as a means to assure food safety'
1993	EU Commission 93/43/ECC recommended use of 5 HACCP principles Codex'93 Guidelines
1995	5 HACCP principles mandatory in EU
1997	Codex Document on HACCP principles and application
1998	FAO/WHO provide guidance for regulatory assessment of HACCP
2003	FAO/WHO develop HACCP guidelines
2004	EC 852/2004 requirement for all food businesses to adopt HACCP principles in EU
2006	Legal requirements to apply HACCP in food businesses (other than primary production) across EU
2006+	Increased worldwide use of HACCP in food safety legislation

Adapted from Corlett (1998), Griffith (2006), Linton (2001), Sperber (2005).

plants (FSIS, 1996). Meat and poultry HACCP implementation was completed in January 2000 (FSIS, 2000a, b). At the 35th Session of the Codex Committee on Food Hygiene in 2003, it was agreed that FAO and WHO would develop HACCP guidelines for small and/or less developed businesses (SLDBs), highlighting potential obstacles and approaches to overcome these obstacles. The FDA defines the term 'small and/or less developed businesses' shall mean businesses that because of their size, lack of technical expertise, economic resources, or the nature of their work, encounter difficulties in implementing HACCP in their food business. The term 'less developed business' refers to the status of the FSMS and not to the number of staff or volume of production (FAO/WHO, 2006a). The highlights of the HACCP system are presented in Table 1.1.

1.1.3 Codex Alimentarius

A Codex Alimentarius programme was initiated in the early 1960s under FAO/WHO control with the specific aim of getting international agreements on food standards and codes of practice which would safeguard the health of consumers and generally encourage good practices in the food trade (Forsythe and Hayes, 1998). The Codex Alimentarius (Latin, meaning Food Law or Code) is a collection of internationally adopted food standards presented in a uniform manner. It also includes provisions of an advisory nature in the form of codes of practice, guidelines and other recommended measures to assist in achieving the purposes of the Codex Alimentarius (FAO/WHO, 2005). The Codex Alimentarius has gained a greater significance since the formation of the World Trade Organisation (WTO). The Agreement on the Technical Barriers to Trade (TBT), which was introduced following the Tokyo Round on World Trade in 1979, had a substantial impact on the establishment of policies on food control. The TBT agreement did not specifically mention Codex but dealt with the aspects of food not directly related to safety such as labelling, quality and packaging and thus impinged on Codex. The WTO, however, recognised Codex as the preferred international organisation for the arbitration and settlement of disputes related to food trade (Ottaway, 2003).

The Codex Alimentarius Commission is committed to protecting the health of consumers, ensures fair practices in the food trade and facilitates international trade in food. The Codex General Principles of Food Hygiene has recommended a HACCP-based approach as a means to enhance food safety and has indicated

how to implement the principles (Codex Alimentarius, 1997). All member nations and associate members of the FAO and WHO can become members of Codex. The membership has increased over the years and 165 countries were Codex members in 2000, representing 97% of the world's population (Ottaway, 2003).

The Codex Guidelines for the application of the HACCP system published in 1993 have been revised and the revised text entitled Hazard Analysis and Critical Control Point (HACCP) system and guidelines for its application was adopted by the Codex Alimentarius Commission in June 1997 in the document 'Codex Alimentarius Commission, Report of the Twenty-Second Session of the Codex Alimentarius Commission, Geneva, June 1997' (http://www.unido.org/userfiles/cracknej/fgfs1.pdf).

The Codex general principles of food hygiene are as follows:

1. Identify the essential principles of food hygiene applicable throughout the food chain, in order to achieve the goal of ensuring that food is safe and suitable for human consumption.
2. Recommend a HACCP-based approach as a means of enhancing food safety.
3. Indicate how to implement those principles.
4. Provide guidance to specific codes which may be needed for sectors of the food chain, processes or commodities, to amplify the hygiene requirements specific to those areas (FAO/WHO, 2005).

Although Codex claims to have 'broad community involvement' to increase consumer protection with internationally recognised scientific food standards, its achievements fall flat under scrutiny. The Codex does not rely on community involvement in its decision-making process; decisions are made by governmental appointees behind closed doors (http://www.citizen.org/documents/codexfactsheet.pdf).

1.1.4 The need for HACCP

To successfully implement HACCP in the food supply system, authorities responsible for food safety should first be aware of the need to move to a system such as HACCP. Until this need is acknowledged, it is unlikely that a commitment at any level can be expected (http://www.unido.org/userfiles/cracknej/fgfs1.pdf). In a survey conducted to find out whether HACCP was a more effective strategy than their current or other method(s) industry groups had used to secure food hygiene, 41% strongly agreed, 50% agreed, while only 9% did not think that the strategy was more effective than their current provisions (Ehiri *et al.*, 1997).

Motivations for adopting HACCP may include the need to:

- reduce the incidence of foodborne disease
- ensure a safe food supply for the population
- promote (facilitate) trade in food products (http://www.unido.org/userfiles/cracknej/fgfs1.pdf).

1.1.5 Hazards (physical, chemical, microbiological)

The regulation defines a food safety hazard as 'Any biological, chemical or physical property that may cause a food to be unsafe for human consumption' (USDA, 1997). While consumers have historically been most concerned with chemical hazards such as pesticide residues and heavy metal contamination, microbiological contaminants and allergens have been the recent focus of public health officials' concerns (Fig. 1.1). The HACCP system addresses and controls all significant hazards associated with a particular product (Goodrich *et al.*, 2005). At a cost of about $1000 per case of disease (Canadian and USA estimates), the economic impact in the Federal Republic of Germany had been valued at more than 10 billion DM (Untermann, 1995). There are three categories of hazards that are considered in a HACCP plan. These are physical, chemical and biological. All types of hazard can enter a food product at any stage during processing (Harris, 1999). Potentially hazardous foods include meats, dairy products, poultry, eggs, cooked foods (beans, pasta, rice and potatoes), cut cantaloupe and raw seed sprouts (McSwane *et al.*, 2000).

1.1.5.1 Physical hazards

Physical hazards include glass, metal, stones, wood, plastic, rubber or pests (typically larger pests). Sand may also be an undesirable foreign material in a prepared salad but it is not likely to cause human illness (Harris, 1999). However, foreign objects which cannot or do not cause illness or injury are not hazards, even though they may not be aesthetically pleasing to the consumers (USDA, 1997). Physical hazards commonly result from accidental contamination and poor food handling practices that can occur at various points in the food chain from harvest to consumer (McSwane *et al.*, 2000). Confirmed cases of foreign materials in US food versus time are presented in Fig. 1.2.

The Canadian Food Inspection Agency (CFIA) defines three classes of physical hazards depending on their likelihood and the severity of the consequences:

- Category I (high likelihood)
- Category II (moderate likelihood)

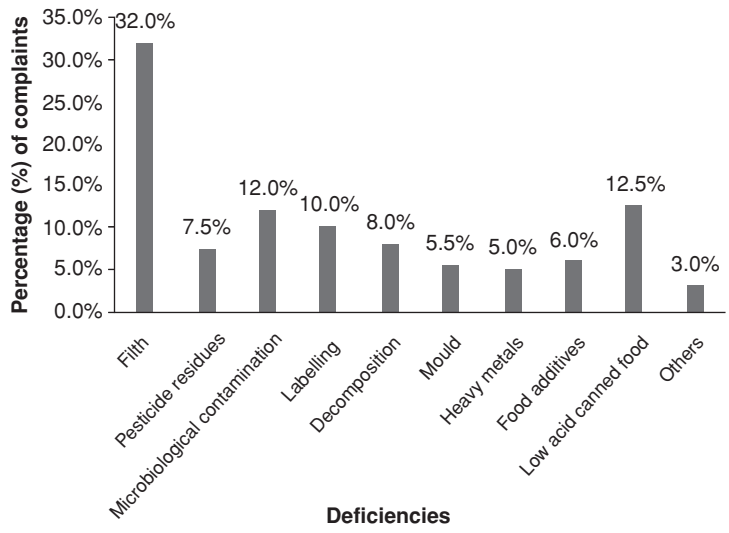

Fig. 1.1 Problems in the international trade in food that are related to deficiencies in basic hygienic measures (FAO, 2000; Orriss and Whitehead, 2000).

- Category III (low risk) (http://www.gov.mb.ca/agriculture/foodsafety/processor/pdf/cfs02s74.pdf).

To prevent physical hazards, wash raw fruits and vegetables thoroughly and visually inspect foods that cannot be washed (such as ground beef). Food workers should be taught to handle food safely to prevent contamination by unwanted foreign objects. Finally, food workers should not wear jewelry when involved in the production of food, except for a plain wedding band (McSwane *et al*., 2000). Nowadays, there are various methods for the detection of foreign materials such as metal detectors, low-energy X-rays etc. which are used in the food industry.

1.1.5.2 Chemical hazards

Chemical hazards include cleaning chemicals, pesticides (including those not applied in or around food processing establishments), allergens, toxic metals, nitrites and nitrates (when added to the product),

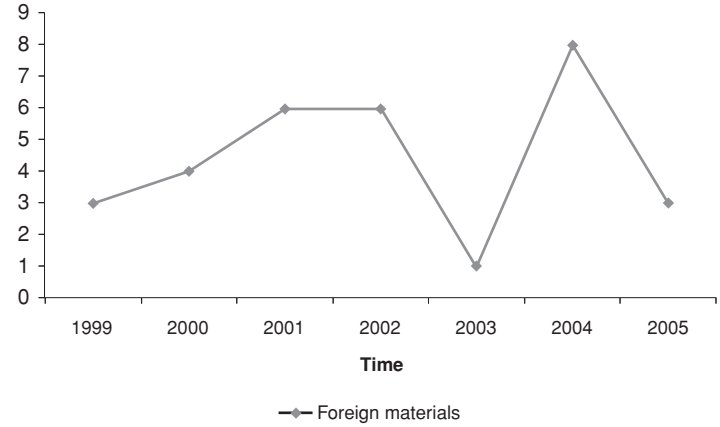

Fig. 1.2 Determined cases of foreign materials in United States versus time. (Adapted from Arvanitoyannis et al., 2006)

plasticisers and packaging migration, veterinary residues (when animals have been given drugs to treat disease in the animal, e.g. antibiotics treatments for mastitis in cows) and chemical additives (when added; Harris, 1999). Between 5 and 8% of children and 1–2% of adults are allergic to certain chemicals in foods and food ingredients. These chemicals are commonly referred to as food allergens (McSwane *et al.*, 2000).

Chemical hazards fall into two categories:

- Naturally occurring poisons, chemicals or deleterious substances are those that are natural constituents of foods and are not the result of environmental, agricultural, industrial or other contamination (e.g. aflatoxins, mycotoxins, shellfish toxins).
- Added poisonous chemicals or deleterious substances are those which are intentionally or unintentionally added to foods at some point in growing, harvesting, storage, processing, packing, or distribution (e.g. pesticides, fungicides, insecticides, fertilisers, drug residues, antibiotics, food additives, lubricants, cleaners, paints, coatings; USDA, 1997).

Because it is impossible to provide a comprehensive list of contaminants, it would be much better to focus on purity of water, raw material supply, workers' poor hygiene and lack of GMP in order to reduce the probability of occurrence of chemical hazards.

1.1.5.3 Biological hazards

Biological hazards include food poisoning bacteria such as *Salmonella*, *E. coli* and *Bacillus cereus*, which are hazardous because they can survive inadequate cooking, grow to harmful levels in stored food given the right conditions and spread from raw foods to 'ready to eat foods' (cross-contamination) (www.cardiff.gov.uk/ObjView.asp?Object_ID=3968). After World War II, serious food safety incidents occurred in the nascent food processing industry. These typically involved *Salmonella* contamination of dried egg or dairy products, *Campylobacter* spp. in canned meat or *Clostridium botulinum* growth or presence in canned foods. The most pressing food safety issues in the food industry nowadays are due to the presence of *E. coli* O157:H7 and salmonellae in raw meat and poultry products and in produce (Sperber, 2005). *E. coli* O157:H7 is usually transferred to foods like beef through contact with intestines of slaughtered animals. Apples used for juice from orchards where cattle or deer graze are also suspected (McSwane *et al.*, 2000). Pathogens come from:

- low quality of raw materials
- poor personal hygiene
- environment (air, water and equipment)
- inadequate cooking
- improper storage/holding temperature
- improper reheating
- cross-contamination – improper segregation of raw and cooked foods
- past use – by time (http://www.jphpk.gov.my/Agronomi/KAV/5HACCP1.pdf; Forsythe and Hayes, 1998).

An annual consumer survey carried out by the Food Marketing Institute (FMI) from 1993 through 1997 showed that the number of people who said they were 'very concerned' about chemical contaminants such as pesticides declined from 79 to 66%. The FMI survey first included questions on microbial contamination in 1995. From 1995 to 1997, microbial contamination topped the list of consumer concerns. By contrast, consumers ranking themselves as very concerned about foods produced using biotechnology have hovered around 15% for the same 3 years (FMI, 2000). Foodborne infections are caused when micro-organisms are ingested and these can multiply in the human body. Infections result when microbial or naturally occurring toxins are consumed in contaminated foods. Micro-organisms or toxins may be introduced directly from infected food animals or from workers, other foods, or the environment during the preparation or processing of food. Poisonous substances may also be produced by the growth of bacteria and moulds in food (Rooney and Wall, 2003).

The numbers and types of bacteria vary from one food or animal species to another, from one geographic region to another, and with production and slaughter or harvesting methods. During production, processing packaging, transportation, preparation, storage and service any food may be exposed to bacterial contamination. The most common biological hazards in meat and poultry are microbiological, although biological hazards may also be due to parasites or zoonotic disease processes (USDA, 1997). Six conditions are required for bacterial growth. They need a nutrient (e.g. meat, poultry, seafood, dairy products, cooked rice, beans, potatoes), a mildly acid environment (pH = 4.6–7.0), a temperature between 5 and 60°C, time (approximately 4 hours to grow to high enough numbers to cause illness), different oxygen requiring environments (aerobic, anaerobic and facultative micro-organisms), and enough moisture (water activity >85 for disease-causing bacteria; Marriott, 1997; McSwane *et al.*, 2000). Microbial cells have a growth cycle of five phases: lag phase (adaptation period), logarithmic growth phases (bacteria multiplication), stationary growth phase (slowdown of growth), accelerated

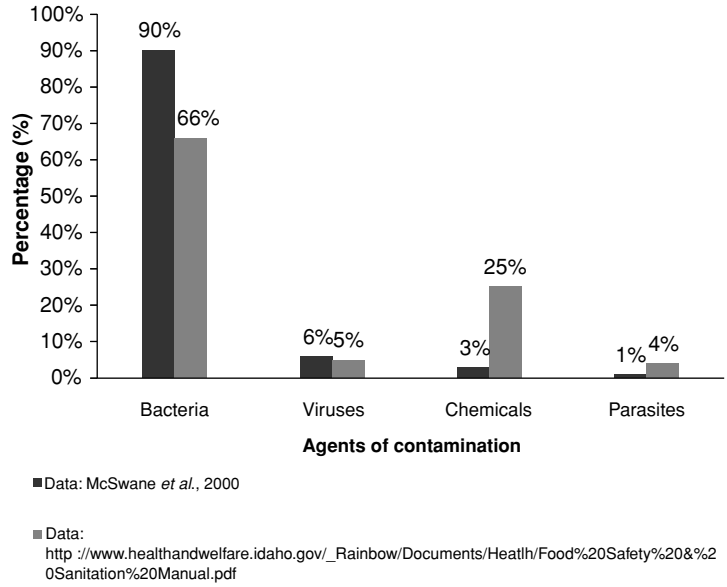

Fig. 1.3 Types of contamination (McSwane et al., 2000; http://www.healthandwelfare.idaho.gov/_Rainbow/Documents/Health/Food%20Safety%20& %20Sanitation%20Manual.pdf).

death phase (rapid death of microbial cells) and reduced death phase (slowdown of death rate; Marriott, 1997). Examples of biological hazards are disease-causing bacteria, viruses, parasites, moulds, yeasts and naturally occurring toxins (Fig. 1.3). Biological hazards cause the most foodborne illness outbreaks and are of the greatest concern to food service managers and health inspectors (http://www.sfdph.org/eh/pubs/foodsafetyfacts/food_hazards.pdf).

Quantitative scientific assessments of the risks from micro-organisms in foods and water on the basis of dose–response relationships and exposure assessment, customarily carried out for chemical contaminants, have been developed for some pathogens, especially in drinking water. Two particular difficulties have to be mentioned for the quantification of microbiological hazards associated with the consumption of foods: the determination of the minimal effective dose and the complicated kinetics of bacterial survival, growth and death in foods which necessitate greater care in the monitoring of bacterial contaminations (Untermann, 1998).

1.1.6 The seven principles of HACCP

The application of HACCP is compatible with the implementation of quality management systems such as the ISO 9000 series and is the system of choice in the management of food safety within such systems (Anon, 2000). One of the benefits of the HACCP system is that it focuses attention on areas where problems potentially may occur, and requires that food service facilities be prepared to deal with problems immediately if they occur (Puckett and Schneider, 1997). The HACCP system consists of seven principles (Fig. 1.4). These principles make up the Codex standard, which has become the reference for international food safety and identified as the baseline for consumer protection under the Agreement on Sanitary and Phytosanitary Measures agreed at the General Agreement on Tariffs and Trade (GATT) negotiations in 1995 (Slatter, 2003).

Principle 1 *Conduct a hazard analysis.* A hazard analysis is the identification of any hazardous biological, chemical or physical properties in raw materials and processing steps, and an assessment of their likely occurrence and potential to cause food to be unsafe for consumption (USDA, 1997). The HACCP team conducts a hazard analysis and identifies appropriate control measures (Corlett, 1998). Hazard analysis is accomplished in two stages: (a) hazard identification based on a review of the origins of possible hazards and (b) hazard evaluation within the frame of the potential significance of each hazard is assessed by considering its severity (referring to health consequences) and its like-

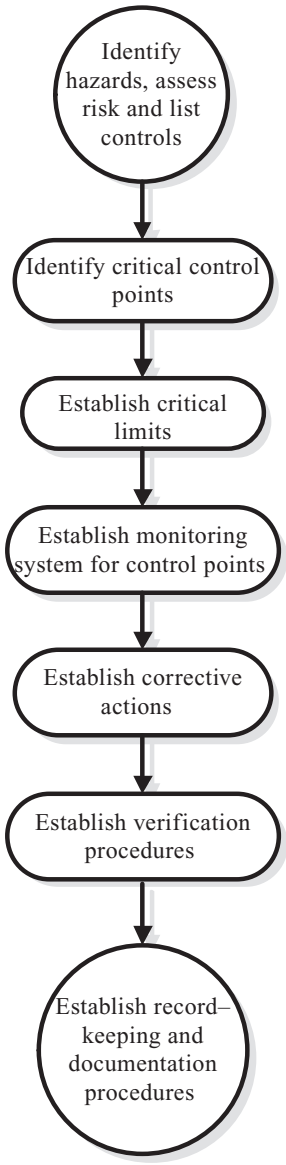

Fig. 1.4 Seven principles involved in developing and operating a HACCP programme (http://www.nzfsa.govt.nz/processed-food-retail-sale/fsp/haccp.pdf; NACMCF, 1997).

liness to occur (based on experience, epidemiological data and available information in the literature). Hazard analysis is completed by listing all significant hazards associated to each step, and all control measures that can eliminate or control these hazards to an acceptable level (Arvanitoyannis and Hadjicostas, 2001). If the hazard analysis is not done correctly and the hazards warranting control within the HACCP system are not identified, the plan will not be effective regardless of how well it is followed (Corlett, 1998).

Principle 2 *Identify the critical control points (CCPs) in the process*. CCPs are steps at which control can be applied and a food safety hazard can be prevented, eliminated or reduced to acceptable levels (Rushing and Ward, 1999). The HACCP team should identify the steps in the production process which are essential for the elimination or significant reduction of the identified hazards from Principle 1. These CCPs are identified through the use of the decision tree (Fig. 1.5). A CCP should be a quantifiable procedure in order for measurable limits and monitoring to be achievable in Principles 3 and 4 (Forsythe and Hayes, 1998). It is not possible to find CCPs for all types of products and hazards. Especially in low-processed products such as fresh meat, there is almost no site at which microbial hazards can be eliminated. Thus, only hygiene concepts using the basic HACCP methodology can be developed (Upmann and Jacob, 2004). Some common points where control can be applied in a process include:

1. chilling to temperatures that minimise microbial growth
2. testing ingredients for chemical residues
3. cooking to specific temperatures for exact times in order to destroy microbial pathogens
4. product formulation control, such as the addition of cultures or adjustment of pH or water activity
5. testing product for metal contaminants
6. processing procedures such as filling and sealing cans
7. slaughter procedures such as evisceration or antimicrobial interventions

(Corlett, 1998; USDA, 1999).

Principle 3 *Establish critical limit(s) for preventive measures associated with each identified CCP.* Once the CCPs have been determined, a critical limit or the amount of acceptable deviation has to be established for each CCP (http://www.qsae.org/web_en/pdf/HACCPImpGuide.pdf). Critical limits for CCPs are expressed as numbers or specific parameters on visual observation, such as time/temperature, humidity, water activity, pH, salt concentration and chlorine level (Corlett, 1998; USDA, 1997). There are two types of critical limits. A critical limit can be an *upper limit* where a set amount or level cannot be exceeded. A critical limit can also be a *lower limit* where a minimum amount is required to produce the safe effect (USDA, 1999). Critical limits are set for product safety and not product quality.

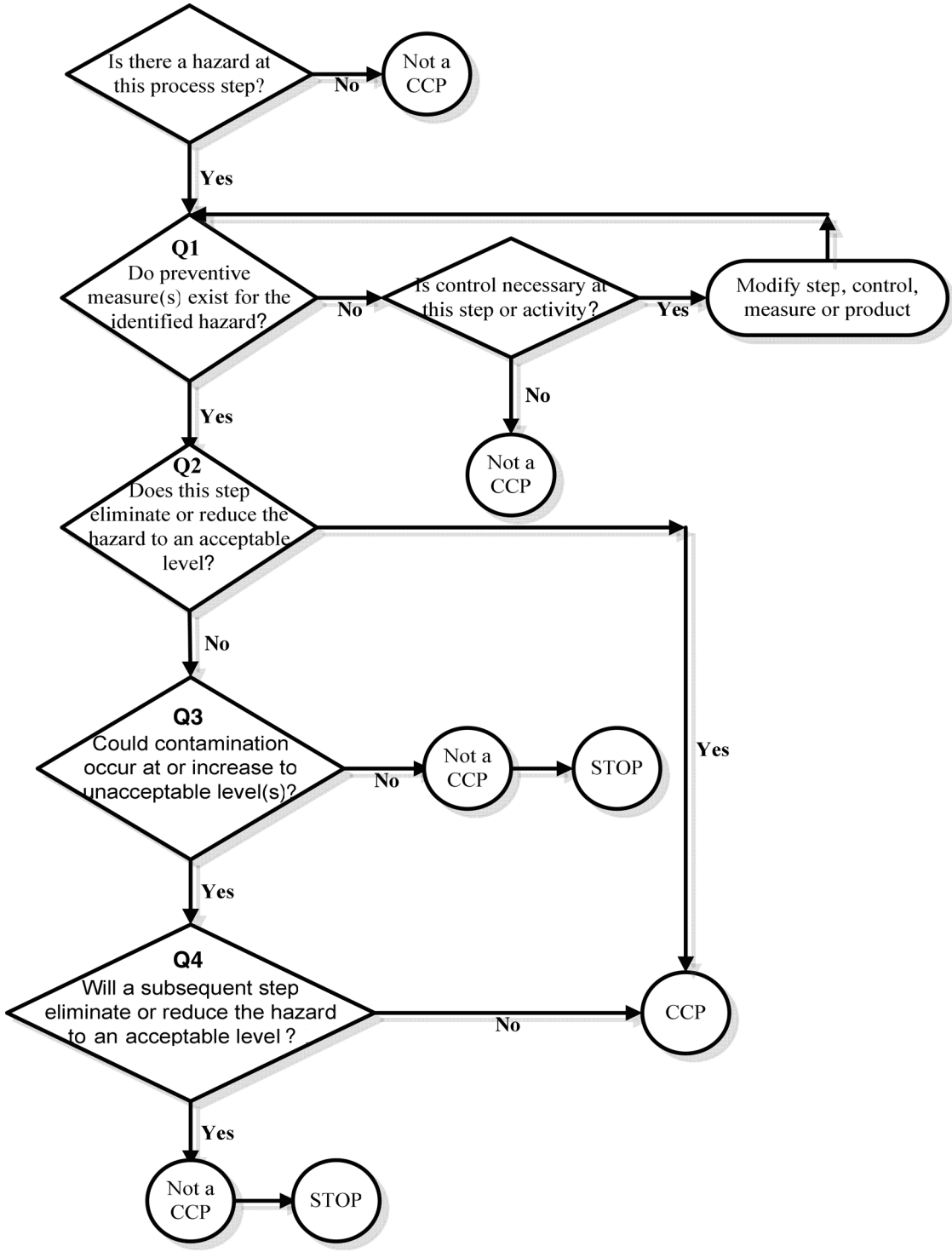

Fig. 1.5 Process step CCP decision tree. (Adapted from Corlett, 1998; Efstratiadis and Arvanitoyannis, 2000; Horchner et al., 2006; http://www.jphpk.gov.my/Agronomi/KAV/5HACCP1.pdf.)

For example, the critical limit for frozen raw poultry storage and shipping would require the product be held below 5°C, which does not constitute frozen but prevents bacterial growth. In a cooked product, an example of a critical limit would be that an internal temperature of the product reaches at least 71°C (http://www.qsae.org/web_en/pdf/HACCPImpGuide.pdf).

Principle 4 *Establish CCP monitoring requirements and procedures for using monitoring results to adjust processes and maintain control.* Monitoring consists of observations or measurements taken to assess whether a CCP is under control. Monitoring is used to determine when a deviation occurs at a CCP and, if it is not continuous, needs to be conducted at a frequency sufficient to ensure that the CCP is under control (Hulebak and Schlosser, 2002). Continuous monitoring is always preferred when it is feasible. When it is not possible, then the HACCP team will need to decide what will be their non-continuous monitoring procedures and how frequently they will be performed. There are several issues to consider when deciding the frequency of non-continuous monitoring checks; the most important is that the procedures should be performed sufficiently often to accurately reflect that the process is under control (USDA, 1999). The most important steps in food production to monitor are:

1. cooking
2. cooling
3. reheating
4. hot holding

(Ropkins and Beck, 2000).

The three basic requirements for developing monitoring procedures for the HACCP plan are:

1. defining the monitoring procedure
2. determining the frequency for monitoring
3. determining who will do the monitoring

(Corlett, 1998).

The following forms are representative of those needed for monitoring the HACCP system in most food plants:

1. raw material evaluation sheet
2. supplier's guarantee
3. cooker log
4. pack room inspection report
5. cooking process validation letter
6. cooking equipment validation letter
7. equipment calibration log
8. corrective action report
9. employee training report

(Corlett, 1998).

Principle 5 *Establish corrective actions to be taken when monitoring indicates that a particular CCP is not under control.* The regulation defines corrective action as 'Procedures to be followed when a deviation occurs'. A deviation is a failure to meet a critical limit (USDA, 1997).

The purpose of corrective actions is:

1. to adjust the process, such as cooking temperatures or cooling rates to maintain control or prevent a deviation
2. to correct the cause of the deviation
3. to re-establish control over the process and CCP
4. to determine the safety and proper disposition of the food being produced while a defect was occurring
5. to maintain records of corrective actions

(Ropkins and Beck, 2000).

All corrective actions cannot be anticipated. An unlisted corrective action should be incorporated into the corrective action document. The corrective action will consist of the decision regarding disposal of non-complying material, correcting the cause of deviation, demonstrating that CCP is once again in control, and, finally, maintaining records of the corrective action (Deodhar, 1999).

Principle 6 *Establish procedures for verification to confirm that the HACCP system is working effectively.* Verification is the application of methods, procedures, tests and other evaluations, in addition to monitoring to determine compliance with the HACCP plan (FAO/WHO, 2001). The verification typically consists of two phases. First, verification that the critical limits established for CCPs will prevent, eliminate or reduce hazards to acceptable limits. Second, verification that the overall HACCP plan is functioning effectively. Once critical limits at each CCP are met, minimal sampling of the final product is needed (McSwane *et al.*, 2000). Basic verification procedures include the following:

1. initiation of appropriate verification inspection schedules
2. review of HACCP plan for completeness
3. confirmation of the accuracy of flow diagram
4. review of CCP records
5. review of records for deviations and corrective actions
6. review of critical limits to verify if they are adequate to control significant hazards
7. validation of the HACCP plan, including on-site review
8. review of the modifications made to the HACCP plan
9. a random sample collection and analysis

10. visual inspection of food production operations to determine that CCPs are under control
11. a review of departures from critical limits and how they were corrected
(Corlett, 1998; McSwane *et al*., 2000).

Principle 7 *Establish documentation concerning all procedures and records appropriate to these principles and their application*. The level of documentation required will depend upon the needs and the complexity of the food business. In a small business, a simple log book or diary may be all that is needed. In a bigger or more complicated business, more detailed or formal documentation will be necessary. Record keeping and documentation systems should meet the needs of the business and be adequate to show that the food safety programme is working (http://www.nzfsa.govt.nz/processed-food-retail-sale/fsp/haccp.pdf).

The HACCP will incorporate documents such as the following:

1. the HACCP plan
2. hazard analysis
3. CCP determinations
4. CCP monitoring sheets
5. corrective actions
6. audit records
7. HACCP team meeting minutes
8. calibration records
(Slatter, 2003).

1.1.7 The 12 stages of the HACCP plan

It is no accident that HACCP evolved at the food processing step of the farm to table supply chain. It is at this step that effective controls, such as cooking, drying, acidification or refining are available to eliminate significant hazards. Two categories of processed food exemplify this fact superbly – pasteurised dairy products and canned foods; note that, with both of these food categories, food safety is assured by process control, not by finished product testing. It is time to stop talking about 'Farm to Table Food Safety' (Sperber, 2005).

1.1.7.1 HACCP team formation

The first step is the formation of the HACCP team which should be trained. Training is often provided by people who are not HACCP practitioners – who are instead lecturers, academics, regulators or former hygiene trainers (Mortimore, 2001). The HACCP team is interdisciplinary and its members (their number is 4–6) could be:

- production manager
- head of analytical laboratory
- head of microbiological laboratory
- personnel manager
- technical manager
- logistics manager.

The HACCP team has to provide the production-specific expertise and experience which are necessary for the development of the HACCP plan (Untermann, 1999). The responsibilities of the HACCP team are:

- organising and documenting HACCP study
- reviewing deviation from critical limits
- internal auditing of HACCP plans
- communicating, educating and training employees in the operation of HACCP system
- understanding the stages of the process the team will be monitoring
(http://www.jphpk.gov.my/Agronomi/KAV/5HACCP1.pdf).

1.1.7.2 Describe product

A complete description of the product by providing information about the ingredients, processing methods, retail, packaging and storage conditions should aim at identifying any possible hazards occurring to the product and that which the product may cause (Arvanitoyannis and Hadjicostas, 2001). The following questions should be answered for the product description:

1. What is the common name of the product?
2. How is the product to be used?
3. What type of packaging encloses the product?
4. What is the length of shelf life of the product, at what temperature?
5. Where will the product be sold? *Who is the intended consumer and what is the intended use? (*Regulatory requirement)
6. What labelling instructions are needed?
7. Is special distribution control needed? (USDA, 1999).

1.1.7.3 Identify intended use

Describe the normal expected use of the food. The intended use consists of information on whether the

product has to be prepared prior to consumption, e.g. by heating or whether it can be consumed directly. With regard to a possible acceptable risk level for a food safety hazard it has to be stated for which group of the population the food is intended (Untermann, 1999). The intended consumers may be the general public or a particular segment of the population (e.g. infants, immunocompromised individuals, the elderly etc.) (NACMCF, 1997).

1.1.7.4 Construct flow diagram

The flow diagram should be constructed by the HACCP team which should be fully familiar with the process. The flow diagram should cover all steps in the operation. When applying HACCP to a given operation, consideration should be given to steps preceding and following the specified operation (FAO/WHO, 2001). A correct flow diagram that identifies all the steps involved in the process should be drawn. The flow diagram may also include steps prior to and after the processing that takes place in the establishment (Fig. 1.6; Arvanitoyannis and Hadjicostas, 2001).

1.1.7.5 On-site confirmation of flow diagram

It is important to check that the flow diagram is accurate by physically checking it against activities and that it includes exceptional items such as breakdowns, rework and cleaning. The team should also check that the flow diagram is correct for any shift pattern (Slatter, 2003). The on-site assessment will normally involve an initial meeting with relevant personnel to explain the nature and extent of the review and to promote cooperation during the assessment. At this stage, any additional documentation required for an on-site review could also be requested and examined (Motarjemi, 2000).

1.1.7.6 On-site verification of flow diagram

The HACCP team should confirm the processing operation against the flow diagram during all stages and hours of operation and amend the flow diagram where appropriate (FAO, 1998). Modifications should be made to the flow diagram as necessary and documented. After these five preliminary tasks have been completed, the seven principles of HACCP are applied (Corlett, 1998).

List all potential hazards associated with each step, conduct a hazard analysis and consider any measures to control identified hazards (see Principle 1)

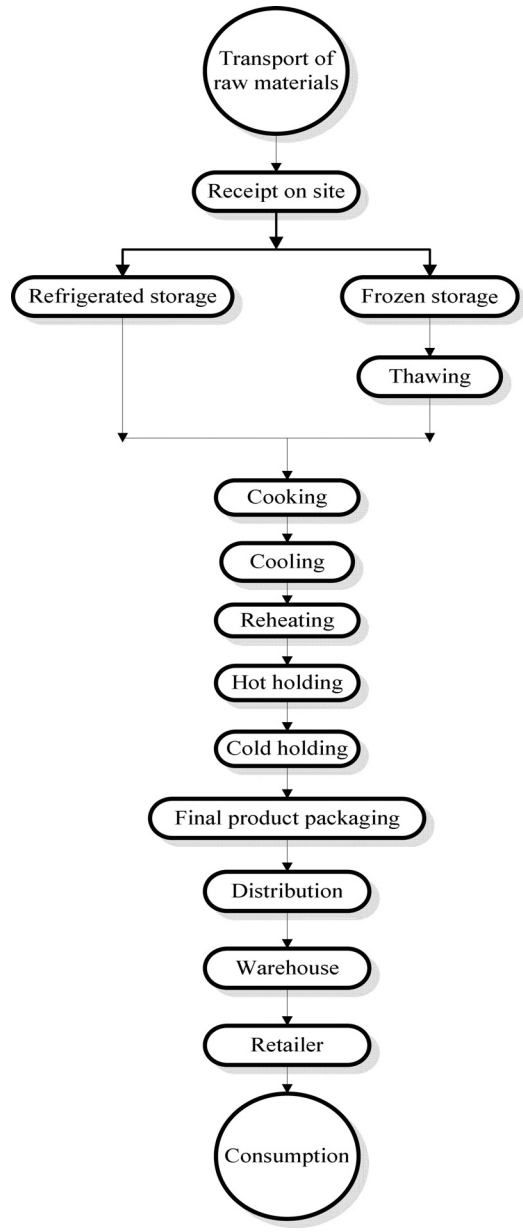

Fig. 1.6 Generalised flow diagram of typical production process (FDA, 1999; Harrigan and Park, 1991; http://www.foodsci.purdue.edu/publications/foodsafety/food_safety-3.html).

Determine CCPs (see Principle 2)
Establish critical limits for each CCP (see Principle 3)
Establish a monitoring system for each CCP (see Principle 4)

Establish corrective actions (see Principle 5)
Establish verification procedures (see Principle 6)
Establish documentation and record keeping (see Principle 7)

1.1.8 HACCP failure

The paradox between the increase in foodborne diseases and the implementation of the HACCP system originates from a misunderstanding of what HACCP is, its role in public health and what can be achieved by its application. The HACCP system *per se* does not make food safe, but it is its 'correct application' that can make a difference. Neither is the HACCP system the magic wand which can turn unsafe food into safe food. The HACCP system should not be a tool for politicians to gain the confidence of consumers (Motarjemi and Käferstein, 1999). Like any other system, HACCP has some vulnerable points, and these may be the major drawback for its non-international application during recent years (Arvanitoyannis and Traikou, 2005). A list, by no means complete, of some of the most common problems reported when reviewing HACCP plans:

- Only some of the principles are applied (mainly failure to apply Principles 4 and 5).
- The principles have not been applied appropriately (not identifying hazards properly).
- The HACCP plan is a 'paper exercise' and is not implemented in practice.
- The HACCP plan is over-complicated.
- Critical limits that are not adequate and not supported by scientific studies.
- Corrective actions do not address the product involved in a deviation.
- Lack of coordination among responsible authorities, public and private sectors.
- Lack of understanding and staff training.
- Lack of commitment by management.
- Regulations and procedures that are not efficient.
- Insufficient education and motivation of consumers and food handlers on food protection task

(Arvanitoyannis and Traikou, 2005; Bernard, 1998; Forsythe and Hayes, 1998; Marriott, 1997; McSwane *et al.*, 2000; Mitchell, 1998; NACMCF, 1997).

The question that still remains is 'When HACCP appears to fail, is it the fault of the HACCP system itself or does the real failure lie with the people who are trying to implement it?' (Mitchell, 1998).

1.1.9 Prerequisite programmes

The HACCP system will incorporate other existing management systems into its procedures. Typical areas are personal hygiene, GMP, supplier quality assurance and maintenance schedules. These are termed 'Prerequisite Programmes' (PRPs) and are normally in place before the HACCP plan is developed. Prerequisites are systems in their own right and will support the HACCP by taking the control of general hygiene and GMP out of the HACCP plan (Slatter, 2003). PRPs to HACCP, including training, should be well established, fully operational and verified in order to facilitate the successful application and implementation of the HACCP system (FAO/WHO, 2006a). A HACCP system can be effective only if it is based on sound good manufacturing and hygienic practices (GMP/GHP). Consequently, it is the responsibility of the government agencies to ensure that these PRPs are properly implemented before assessing HACCP implementation (Ababouch, 2000). Food safety is not synonymous with HACCP. Food safety is HACCP plus PRPs (Sperber, 2005).

1.1.9.1 Training of personnel

Training is crucial to any food safety system. Poor staff training in food hygiene is a real threat to the safety of food. Staff should understand how food safety knowledge is applied in the food safety programme. Any staff member without commitment to food safety threatens the entire programme (http://www.nzfsa.govt.nz/processed-food-retail-sale/fsp/haccp.pdf). It is important to recognise that employees should first understand what HACCP is and then learn the skills necessary to make it function properly. Specific training activities should include working instructions and procedures that outline the tasks of employees monitoring each CCP. Management should provide adequate time for thorough education and training. Personnel should be given the materials and equipment necessary to perform these tasks. Effective training is an important prerequisite to successful implementation of a HACCP plan (NACMCF, 1997). Staff should have an understanding of:

1. what hazards are and their importance in food safety
2. CCPs and their role in the assurance of product safety
3. critical limits which should be met
4. corrective actions and responsibilities
5. record-keeping requirements
6. the objective of verification procedures

(Slatter, 2003).

The first step in training is usually motivation – explaining that everybody could be a vital link in a chain of events leading either to food poisoning or to product safety. It is important to link 'hygiene conscience' with 'product safety' from the very beginning (Engel, 1998). The trainer most often achieves the best results by keeping the talk short and by working through a set sequence of discrete steps as follows:

1. show the trainees the actual skill they are to acquire
2. demonstrate and explain the operations involved
3. have trainees imitate the necessary actions
4. have trainees practise performing the operations
5. devote at least 50% of the session to trainee practice time

(FAO, 1998).

There are many benefits to proper employee training including:

1. improved customer satisfaction – a well-trained staff provides the service and the quality that customers expect
2. lower turnover – money savings to the organisation, better life quality for the employees, higher client satisfaction
3. lower costs – fewer mistakes by well-trained employees
4. fewer accidents due to experience and good training of employees
5. better quality of products

(McSwane *et al*., 2000).

1.1.9.2 Sanitation

Sanitation is broadly defined by 'all precautions and measures, which are necessary in the production, processing, storage and distribution, in order to assure an unobjectionable, sound and palatable product which is fit for human consumption' (Bakka, 1997). Sanitation is not sterilisation (McSwane *et al*., 2000). The first step of sanitisation is the pre-wash, with the objective of removing gross dirt, followed by alkaline and acid washing (to remove proteins, carbohydrates, lipids and minerals, respectively) (da Cruz *et al*., 2006). This dirt usually contains micro-organisms and nutrients that allow the microbes to grow (Marriott, 1997).

Micro-organisms die at a relatively constant rate in the accelerated death phase. Some things can change the death rate, such as lethal agent or a mixed population of sensitive and resistant cells. Heat, chemicals and radiation can all destroy microbes (Marriott, 1997). Micro-organisms vary in their degree of susceptibility to disinfectants. In general, Gram-positive bacteria are more susceptible to chemical disinfectants while mycobacteria or bacterial endospores are more resistant. The hydrophilic, non-enveloped viruses (adenoviruses, picornaviruses, reoviruses, rotaviruses) are more resistant to disinfection than lipophilic, enveloped viruses (coronaviruses, herpesviruses, orthomyxoviruses, paramyxoviruses, retroviruses; Dvorak, 2005).

Commonly used sanitisers in food establishments are presented below. Sanitisers destroy disease-causing organisms which may be present on equipment and utensils even after cleaning (McSwane *et al*., 2000).

Heat

Heat is the most common method of killing spoilage and pathogenic bacteria in foods (Marriott, 1997). Heat in the form of pressurised steam is the most effective method of sterilisation; moist heat kills micro-organisms at relatively low temperatures by denaturation of protein but proteins are far more stable in dry conditions so that far higher temperatures and/or longer times are necessary to effect a kill using hot air. Moist heat is a favoured disinfecting or sterilising agent because it is non-corrosive, economical, has excellent penetration powers, leaves no residue and is active against the majority of micro-organisms (Forsythe and Hayes, 1998). Bacterial populations killed by heat or chemicals tend to die at constant rates – for example, 90% every 10 minutes (http://webhome.broward.edu/~dweber/MCB2010/Study%20Guides/Ch07_Micro8eStudyGuide.pdf).

Chemicals

Many chemical compounds that destroy micro-organisms should not be used to kill bacteria in or on food. Food processors use chemicals to sanitise equipment and utensils that can cross-contaminate food. These chemicals are rinsed off, so they cannot contaminate food. Sanitising, using heat, has become more expensive, so the food industry uses chemical sanitisers more often (Marriott, 1997). Lactic acid, acetic acid and citric acid also are lethal to many micro-organisms. Several other weak acids (e.g. benzoic acid, sorbic acid, sulphur dioxide etc.) are used as preservatives (Harrigan and Park, 1991). The basic characteristics of the ideal chemical agent are:

1. capacity to kill all microbes
2. soluble in water
3. stable on standing
4. not lose activity over time

5. non-toxic to humans and animals
6. low persistence/OM binding
(http://www.eeescience.utoledo.edu/Faculty/Sigler/COURSES/Microbial%20Ecology%20Lecture/12%20-%20Controlling%20microbes.pdf).

Radiation

The process involves exposing the food, either packaged or in bulk, to carefully controlled amounts of ionising radiation for a specific time to achieve certain desirable objectives. When microbes present in the food are irradiated, the energy from the radiation breaks the bonds in the DNA molecules, causing defects in the genetic instructions. Unless this damage can be repaired, the organism will die or will be unable to reproduce (http://mightylib.mit.edu/Course%20Materials/22.01/Fall%202001/food%20irradiation.pdf). Many different kinds of irradiated food were tested over the years such as fruits (bananas, strawberries, mangoes); vegetables (onions, potatoes, peas, carrots, cabbage); grains (wheat flour); meat (fish, chicken, beef); beans (cocoa beans, coffee beans) and various combinations of these and other foods (Hammond *et al*., 1996). Efficiency of irradiation is affected by a variety of factors such as temperature, protein content of the suspended medium, water activity, presence of oxygen etc. The greater the dose of irradiation the more extensive is the change in organoleptic quality of the food. One of the anxieties surrounding the introduction of irradiation of foods is that the process may be used to treat food that would otherwise be detectable as unacceptable, in which possibly toxins had already accumulated, for example (Harrigan and Park, 1991).

Filtration

Filtration can act as a consistent and effective barrier for microbial pathogens and may in some cases be the only treatment barrier (e.g. for removing *Cryptosporidium* oocysts by direct filtration when chlorine is used as the sole disinfectant) (http://www.who.int/water_sanitation_health/dwq/wsp170805chap6.pdf).

Bacteria and larger micro-organisms can be removed from otherwise clear liquids by filtration through membranes which have holes with a mean pore size of 0.2 μm (Harrigan and Park, 1991). The membrane processes most commonly used to remove microbes from drinking water are microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO). There are very few contaminants that cannot be removed by membrane processes (http://www.who.int/water_sanitation_health/dwq/wsp170805chap6.pdf).

1.1.9.3 Good manufacturing practices

Within the food factory, there should be management procedures aimed at the application of codes of Good Manufacturing Practices (GMPs; Harrigan and Park, 1991). GMPs provide general rules for the manufacture, handling and preparation of various kinds of food products. It aims at safeguarding good hygienic and sensory quality traits and may be regarded as an obligation to bestow great care upon production. GMP principles have been developed over a number of years and are now regarded as the foundation on which the production of safe food is based (Upmann and Jacob, 2004). In July 2002, Food and Drug Administration (FDA) formed a Food GMP Modernization Working Group to examine the effectiveness of current food GMPs given the many changes that have occurred in the food industry since 1986. The Working Group has been researching the impact of food GMPs on food safety, as well as the impact (including economic consequences) of revised regulations. Part of the group's current effort, as of June 2004, is to find out which elements of the food GMPs are critical to retain and which should be improved. FDA is now holding public meetings to obtain the public's comments to assist in this effort (U.S. Food and Drug Administration, 2004). In the UK, the Institute of Food Science and Technology publishes guides to GMP (GMP 5, 2007).

Industries that have adopted the GMPs have the following results amongst others:

1. Better quality, safer products, decrease in incidence of consumer complaints.
2. Better, more agreeable, cleaner and safer working environment.
3. Greater employee motivation and productivity and improved psychological conditions
(da Cruz *et al*., 2006).

The plant management is expected to take all reasonable measures and precautions to ensure the following:

Personnel

- disease control
- adequate personal cleanliness
- washing hands thoroughly before starting work, and after using the toilet, handling money, handling anything dirty
- use of gloves
- wear protective clothing, suitable footwear, hair coverings

- avoid smoking, eating, chewing, spitting, sneezing or coughing in the production area
- removing all unsecured jewelry and other objects that might fall into food (Corlett, 1998; FAO, 1998; Forsythe and Hayes, 1998; Marriott, 1997).

Buildings and facilities

- located away from environmentally polluted areas, areas subject to flooding, areas prone to infestations of pests and areas where wastes cannot be removed effectively
- adequate supply of potable water, natural gas, electricity, fuel and other utilities
- adequate drainage and waste disposal systems, ventilation system to minimise odours and vapours, air conditioning and dust control
- walls should be smooth, waterproof, with no ledges and overhangs
- floors made of materials that are impervious, durable, resistant to grease, cleaning agents and to biochemical and microbial attack, free from cracks, crevices, non-slip-surface, easy to clean
- doors should generally be either opened automatically, or provided with heavy-duty plastic strips which permit easy access by personnel and essential traffic (e.g. fork-lift trucks)
- roofing is normally flat or slightly pitched and is supported by trusses or beams, can be a source of natural light, opening windows not recommended
- adequate lighting in hand-washing areas, dressing and locker rooms, toilet and rooms where food is examined, processed or stored
- pest control (insects, flies, cockroaches, moths and beetles, rodents)
  (Corlett, 1998; FAO, 1998; Forsythe and Hayes, 1998; Jarvis, 1999; Marriott, 1997; McSwane *et al*., 2000).

Equipment

- all surfaces in contact with food should be smooth, not porous, inert, visible for inspection, accessible for manual cleaning, made of non-toxic material, corrosion-resistant, designed to resist the extended use, cleaning compounds and sanitising agents
- equipment should be readily disassembled for inspection and manual cleaning, designed to protect the contents from external contamination, sanitised with approved sanitiser and rinsed with potable water if required, equipped with rounded corners and edges (Corlett, 1998; Forsythe and Hayes, 1998; McSwane *et al*., 2000; http://www.hi-tm.com/RFA/Mfg-ppsm/3-prereq-5-06.pdf).

Production and process controls

- no raw material or ingredient should be accepted if it is known to contain parasites, undesirable microorganisms, pesticides, veterinary drugs or toxic, decomposed or extraneous substances
- checking of raw materials that come into the plant by collecting samples to decide if they should accept or reject deliveries
- raw material should be washed or cleaned (if necessary) to remove soil or other contaminants
- inspection of the overall condition of the trucks used to transport low-moisture raw materials, for areas where food and dust collect, for insect activity (frozen raw materials and other ingredients should be kept frozen)
- the storage rooms used for food materials should be clean, provide adequate space for inspection, good air circulation, correct temperature and humidity. Food materials should not be placed directly on the floor
- equipment should be sited so that it can be easily operated, cleaned, inspected and maintained, not close to walls, ceilings or other equipment
- packaging materials should be hygienic, odourless, not reacting with either the contained food or the surrounding atmosphere
- waste food materials should be disposed of in an appropriate manner
- cleaning materials should not be left in processing areas
- finished products should be labelled and isolated pending checks for conformity with the product specification
- defective products should remain isolated pending a decision on reworking, recovery or disposal
- final products approved for release should be removed into the relevant warehouse area
  (Corlett, 1998; FAO, 1998; Forsythe and Hayes, 1998; Jarvis, 1999; Marriott, 1997).

1.1.10 Control measures

Control measures are grouped into three groups as follows:

- PRPs that manage the basic conditions and activities
- operational PRPs that manage control measures that the hazard analysis identifies as necessary to control identified hazards to acceptable levels

- a HACCP plan to manage control measures that the hazard analysis identifies as necessary to ensure control of identified hazards to acceptable levels (CCPs; ISO 22000:2005b).

After biological, chemical and physical hazards identification for each processing step and each ingredient, it is time to identify measures needed to prevent hazards from compromising the safety of the final product (FAO, 1997).

The following are examples of control measures for physical hazards:

1. Specifications for raw materials and ingredients and vendor certification that unacceptable physical hazards or levels are not present.
2. Use of magnets, metal detectors, sifter screens, destoners, clarifiers and air tumblers.
3. Ensuring that GMPs are followed and that no physical contamination occurs to the food through the building facilities, work surfaces or equipment (FAO, 1998).

Some of the measures you can use to prevent chemical hazards are:

1. use only approved chemicals
2. have detailed product specifications for chemicals entering the plant
3. maintain letters of guarantee from suppliers
4. inspect trucks used to ship final product
5. proper labelling and storage of chemicals
6. proper training of employees who handle chemicals (Corlett, 1998).

Control measures taken to prevent biological hazards are:

Bacterial hazards

1. time/temperature control (refrigeration, storage time)
2. heating and cooking processes to eliminate or reduce micro-organisms
3. cooling and freezing
4. fermentation and/or pH control
5. addition of salt or other preservatives which may inhibit micro-organism growth
6. drying which may use heat to kill or remove micro-organisms
7. source control (examination of raw materials and ingredients from suppliers).

Viral hazards

1. cooking processes (heating, cooking, steaming, frying, baking) which may destroy viruses

Parasite hazards

1. dietary control
2. inactivation (heating, drying, freezing)
3. visual examination for parasites (seafood.ucdavis.edu/haccp/training/slides/chapt05.ppt; FAO).

1.1.11 Advantages of HACCP

Food companies that have had effective sanitation and HACCP programmes have a number of positive operating characteristics that distinguish them from companies that do not have these programmes (Corlett, 1998).

- Application of HACCP system throughout the food chain from the primary producer to the consumer.
- More effective use of resources, savings and more timely response to food safety problems.
- Internationally recognised.
- The application of HACCP systems can promote international trade by increasing confidence in food safety.
- The HACCP system allows for the identification of conceivable, reasonably expected hazards, even where failures have not previously been experienced. It is therefore particularly useful for new operations.
- Staff and business owners gain confidence and are better equipped for informed discussion on food safety measures with food inspectors, third-party auditors, consultants, trading partners, consumers and others.
- The development of a HACCP system can lead to improved education and awareness of staff working in SLDBs and staff members are empowered when their input is sought and valued.
- The HACCP system has strengthened the regulatory approach to food safety by providing food control authorities with an opportunity to revisit their method of food inspection and the training provided to food inspectors.
- More focused control on processes critical to food safety, with the flexibility to accommodate additional changes in production, quality or other specific measures, e.g. control of allergens or emerging pathogens.
- Demonstrable improvements to food quality and safety standards, thereby reducing the potential for foodborne disease, customer complaints, wastage and damage to the reputation of the business
  FAO/WHO, 2006a; FSA, 2001; http://www.jphpk.gov.my/Agronomi/KAV/5HACCP1.pdf; http://www.unido.org/userfiles/cracknej/fgfs1.pdf; Motarjemi and Käferstein, 1999).

1.1.12 Disadvantages of HACCP

- Resource-intensive during development, unless supported by extensive structure of trade associations or other industry groupings.
- Needs to be validated for effectiveness.
- Difficult to anticipate all hazards introduced by subtle variations on seemingly standard processes thus needs constant vigilance and updating.
- Element of technical knowledge required to adopt them.
- Perceived complexity and bureaucracy – many smaller businesses regard HACCP as complicated and bureaucratic.
- Lack of knowledge and adequate training – many small businesses remain unaware of HACCP or lack sufficient in-house knowledge and training about the risks associated with their procedures to put in place or maintain effective HACCP-based controls.
- The costs of ongoing training against a backdrop of high staff turnover, typical in the industry, can also be prohibitive for many smaller food businesses (FAO/WHO, 2006a; FSA, 2001).

1.2 ISO 22000

1.2.1 Introduction to ISO 22000

ISO 22000 is the new international generic FSMS standard for food safety management systems. It defines a set of general food safety requirements that apply to all organisations in the food chain. These requirements are listed in sections 4, 5, 6, 7 and 8 of ISO 22000 (see Section 2.8). Recognised worldwide, this universal standard harmonises key requirements and overcomes the difficulties of various food safety standards by region, country, activity, organisation and food-type (http://www.foodsafety.uk.sgs.com/westbury_dairies_case_study-4.pdf).

If an organisation is part of the food chain, ISO 22000 requires the establishment of a food safety management system (FSMS) and usage of this system to ensure that food products do not cause adverse human health effects (http://www.praxiom.com/iso-22000-intro.htm). The requirements of ISO 22000 may apply to all types of organisations within the food chain ranging from feed producers, primary producers, food manufacturers, transport and storage operators, subcontractors to retail and food service outlets, together with inter-related organisations such as producers of equipment, packaging materials, cleaning agents, additives and ingredients (http://www.nsai.ie/IR/index.cfm/area/page/information/ISO 22000).

Organisations are cognisant of the need to demonstrate and provide evidence of their ability to provide safe food (http://www.nsai.ie/IR/index.cfm/area/page/information/ISO 22000). ISO 22000 will help these organisations to establish an FSMS and implement it in the food plant with proper improvement and update of the FSMS system. This standard promotes conformity of products and services to international standards by providing assurance about quality, safety and reliability (Tajkarimi, 2007).

The ISO 22000 standard intends to define the food safety management requirements that companies need to meet and exceed in order to comply with food safety regulations all over the world. It is intended to be one standard that encompasses all the consumer and market needs. It speeds and simplifies processes without compromising other quality or safety management systems (http://www.foodsafety.sgs.com/what_is_iso_22000). ISO 22000 uses generally recognised methods of food safety management such as interactive communication across the food chain, system management, control of food safety hazards through PRPs and HACCP plans, and continual improvement as well as periodic updating of the management system (http://www.degrandison.ie/275-FSMS.htm). Furthermore, the requirement of *Emergency preparedness and response* plan (see 5.7) of ISO 22000 is also a basic requirement of ISO 14001 which is the worldwide Environmental Management System (EMS; Culley, 1998). This standard has many elements in common with ISO 9001, it has its roots in BS 7750 (Quality Standard), and it is also related to Eco-Management and Audit Regulation (EMAR). One of the strengths of ISO 14001 is that it is not a performance standard. It does not specify how the requirements of any section should be satisfied, nor does it specify levels of environmental performance that an organisation should achieve (Ritchie and Hayes, 1998).

The standard has become necessary because of the significant increase of illnesses caused by infected food in both developed and developing countries. In addition to the health hazards, foodborne illnesses can give rise to considerable economic costs including medical treatment, absence from work, insurance payments and legal compensation. As a result, a number of countries have developed national standards for the supply of safe food and individual companies and groupings in the food sector have developed their own standards or programmes for auditing their suppliers (http://www.iso.org/iso/en/commcentre/pressreleases/archives/2005/Ref959.html).

While ISO 22000 can be implemented on its own, it is designed to be fully compatible with ISO 9001:2000 and companies already certified to ISO 9001 will find

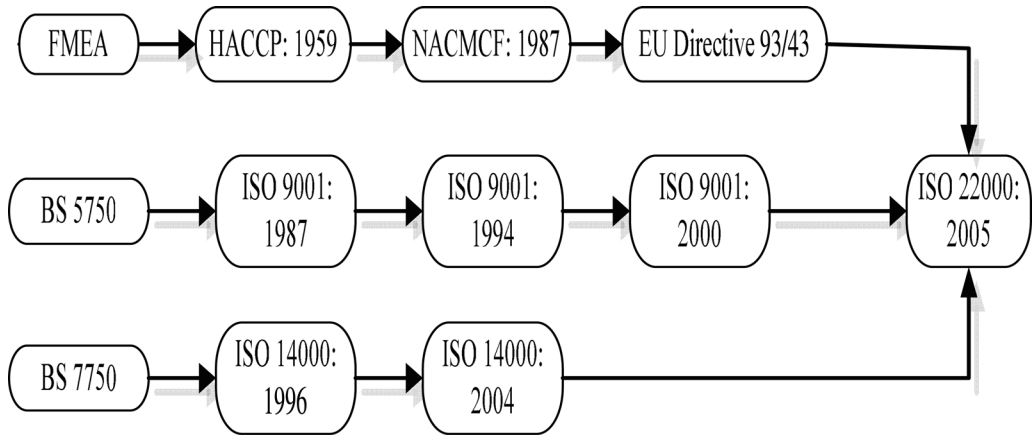

Fig. 1.7 The standards/systems that led to the development of ISO 22000.

it easy to extend this to certification to ISO 22000 (Fig. 1.7) (http://www.iso.org/iso/en/commcentre/pressreleases/archives/2005/Ref959.html). ISO 9001: 2000 on quality management does not deal specifically with food safety. As a result, many countries, such as Denmark, the Netherlands, Ireland and Australia amongst others developed voluntary national standards and other documents specifying auditable requirements for FSMS (Faergemand and Jespersen, 2004).

1.2.2 An introduction of ISO 22000

The challenge for ISO 22000 is that it should be recognised by all segments in the food chain. It seems certain that the HACCP standards will be replaced with ISO 22000. What is not yet certain is whether the retailer will accept it. One factor in favour of ISO 22000 is that its intent is global. Thus, as produce is increasingly sourced globally, confidence can be gained from one single universally accepted ISO standard (http://bvqi.com/webapp/servlet/FileServlet?mode=download&...+Magazine.pdf).

ISO 22000:2005 is the first in a family of standards that includes the following documents:

- ISO/TS 22003, *Food safety management system – Condition for organisations which make certification and inspection of food safety management system*, defines the rules applicable for the audit and certification of a food safety management system (FSMS) complying with the requirements given in ISO 22000 (or other sets of specified FSMS requirements), and provides the necessary information and confidence to customers about the way certification has been wanted to their suppliers. Published in the first quarter of 2006.
- ISO/TS 22004, *Food safety management system – Guide-related practicing of ISO 22000:2005*, provides generic guidance that can be applied in the use of ISO 22000. Published in November 2005.
- ISO 22005, *Monitoring in bait and food chain – General principles and guide for system preparation and design*, is in preparation at the time of publication of this text and will initially be circulated as a Draft International Standard (http://www.wcs.com.tr/certification/ISO22000_haccp.htm; http://www.iso.org/iso/en/commcentre/pressreleases/archives/2005/Ref959.html; http://www.bulltek.com/English_Site/ISO9000_Introduction_English/HACCP_English/ISO_22000/iso_22000.html).

The standard has three parts:

- Requirements for GMP or pre-requisite programme
- Requirements for HACCP principles of the Codex Alimentarius.
- Requirements for management system (http://www.nsf-isr.org/newsroom/press_release.asp?p_id; http://www.lrqa.co.uk/products/otherproducts/ISO22000/).

The standard has the following objectives:

- to enhance food safety
- to ensure consumer protection
- to strengthen consumer confidence

- to improve cost efficiency throughout the food supply chain
- to comply with the Codex HACCP principles
- to harmonise the voluntary international standards
- to provide an auditable standard that can be used either for internal audits, self-certification or third-party certification
- the structure to align with ISO 9001:2000 and ISO 22000:2005
- to provide communication of HACCP concepts internationally (http://www.degrandison.ie/275-FSMS.htm; http://www.ourfood.com/foodsafety/FoodSafetyAndControlSystem15.pdf; Tajkarimi, 2007).

1.2.3 History of ISO 22000

In 2001, ISO started the development of an auditable standard, which further defines HACCP's role in FSMS and culminated in the newly formed ISO 22000 (http://www.foodsafety.sgs.com/what_is_iso_22000). The publication of ISO 22000 was complemented by an ISO Technical Specification (ISO/TS 22004) giving guidance on the implementation of the standard, with a particular emphasis on small- and medium-sized enterprises. Working Group 8 (WG 8) on FSMS prepared ISO 22000 and ISO/TS 22004, which were both published in 2005 (FAO/WHO, 2007). Another Technical Specification (ISO/TS 22003) was also published explaining certification requirements applicable when third-party certification is used (Frost, 2005). The Draft International Standard ISO/DIS 22000 was issued on 3 June 2004. The deadline for comments was 3 November 2004. ISO 22000 was expected to be available as an International Standard in 2005 (Faergemand and Jespersen, 2004). ISO circulated the final draft of the standard to the national standard bodies that make up its membership for a 2-month voting period, ending on 5 July 2005. The standard can be applied on its own, or in combination with other management system standards such as ISO 9001:2000, with or without independent (third party) certification of conformity (Frost, 2005). The working group that developed ISO 22000 has representatives from 14 countries and input from 13 others representing all continents. In the working group, there are also representatives from organisations such as the Codex Alimentarius, the Global Food Safety Initiative (GFSI) and the Confederation of Food and Drink Industries of the EU (CIAA) (http://www.haccp.com.au/bulletins/bulletin3.pdf; http://www.lrqa.co.uk/products/otherproducts/ISO22000/). The timetable for the development of ISO 22000 is given in Table 1.2.

Table 1.2 Timetable for the development of ISO 22000.

Date	Event
2001	Development of the standard
3 June 2004	Draft International Standard ISO/DIS 22000
3 November 2004	Deadline for comments on the draft International Standard
5 July 2005	Final draft of the International Standard

1.2.4 Relationship of ISO 22000 to HACCP

The design and implementation of an organisation's food safety management system are influenced by varying factors, in particular food safety hazards, the products provided, the processes employed and the size and structure of the organisation. This Technical Specification provides guidance on the use of ISO 22000, which is based on the principles of HACCP as described by the Codex Alimentarius Commission and is designed to be applied together with relevant standards published by that organisation (ISO 22000:2005b). ISO 22000 will dynamically combine the HACCP principles and application steps with PRPs, using the hazard analysis to determine the strategy to be used to ensure hazard control by combining the PRPs and the HACCP plan (Table 1.3; Faergemand and Jespersen, 2004).

1.2.5 Application of ISO 22000

ISO 22000:2005 applies to all organisations, regardless of their size, that impact the food chain (http://www.nsf-isr.org/newsroom/press_release.asp?p_id=11944; http://www.nsai.ie/IR/index.cfm/area/page/information/ISO 22000). The standard was drafted to serve the needs of not just food producers and manufacturers, but also virtually every other organisation that participates in the food supply chain. ISO 22000 is written with a structure compatible to other management system standards in the light of ISO 9001:2000 (applying ISO 15161 as guideline) while combining HACCP MS/Codex HACCP (http://www.bulltek.com/English_Site/ISO9000_Introduction_English/HACCP_English/ISO_22000/iso_22000.html). Direct or indirect organisations which can be certified with ISO 22000 standard are the following:

(a) Direct organisations
- farmers
- harvesters
- bait producers
- food component producers

Table 1.3 Cross-references between the HACCP principles and application steps and clauses of ISO 22000:2005 (ISO 22000:2005a; Surak, 2003b).

HACCP	ISO 22000:2005
Assemble HACCP team	7.3.2 Food safety team
Describe product	7.3.3 Product characteristics
	7.3.5.2 Description of process steps and control measures
Identify intended use	7.3.4 Intended use
Construct flow diagram	7.3.5.1 Flow diagram
	7.4.1 Hazard analysis
	7.4.2 Hazard identification and determination of acceptable levels
Principle 1	
Conduct hazard analysis	7.4.3 Hazard assessment
	7.4.4 Selection and assessment of control measures
Principle 2	
Determine CCPs	7.6.2 Identification of CCPs
Principle 3	
Establish critical limits	7.6.3 Determination of critical limits for CCPs
Principle 4	
Establish a monitoring system	7.6.4 System for the monitoring of CCPs
Principle 5	
Establish corrective actions	7.6.5 Actions when monitoring results exceed critical limits
Principle 6	
Establish verification procedures	7.8 Verification planning
Principle 7	
Establish documentation and record keeping	4.2 Documentation requirements
	7.7 Updating of preliminary information and documents specifying the PRPs and the HACCP plan

- food producers
- food sellers
- food services
- ready made food companies
- organisations which service cleaning, sanitising
- carriers, storage, distribution etc.

(b) Indirect organisations

- producers of equipment
- package materials
- ingredients and additives
- organisations etc. producing other elements which contact with food (http://www.wcs.com.tr/certification/ISO 22000_haccp.htm; http://www.qmi.com/registration/foodsafety/ISO 22000/Default.asp?language=english; Pillay and Muliyil, 2005).

1.2.6 Benefits of ISO 22000

Adopting the ISO 22000 standard provides the company with competitive efficiencies worldwide. With registration to ISO 22000, the ensuing advantages are:

- incorporation of legal and regulatory requirements relating to food safety including HACCP systems
- a uniformly auditable standard
- a drive for continuous improvement
- improved internal and external communications
- improved documentation
- improved compliance with hygiene regulations
- improved food safety hazard control
- easy to understand, apply and recognise
- facilitates traceability and clear communication across the supply chain
- clear responsibilities and authorities agreed for all staff
- resource optimisation (internally and along the food chain)
- valid basis for taking decisions
- provides a framework for third-party certification
- can be applied independently
- allow small and/or less developed organisations to implement an externally developed system
- speeds and simplifies processes, increases efficiency and reduces costs without compromising existing or other quality or management systems
- applicable to all organisations in the global food supply chain
- the structure aligns with the management system clauses of ISO 9001 and ISO 14001
- all control measures are subjected to hazard analysis
- better planning – less post-process verification

- systematic management of PRPs
- a systematic and proactive approach to identification of food safety hazards and development and implementation of control measures
- enables streamlined communication and collaboration for quicker, more informed decision making about hazards with supply chain partners
- increased international acceptance of food products
- reduces risk of product/service liability claims
- ensures safety of food products
- greater health protection
- job productivity and satisfaction of employees are increased
- employees become conscious about hygiene and food safety
- can be applied by all manufacturers and participants in the entire food chain supply
- food wastes (food decaying etc.) fees decrease to minimum
- work environment gets better
- it is a trusted system which was confirmed by FAO/WHO
  (http://www.wcs.com.tr/certification/ISO22000_benefits.htm;
  http://www.bis.org.in/cert/fsms.htm;
  http://www.organaqsis.com/Domaines/anglais/Hyg_secu_alim.htm;
  http://www.bsi-global.com/en/Assessment-and-certification-services/management-systems/Standards-and-Schemes/ISO-22000/Benefits/;
  http://www.degrandison.ie/275-FSMS.htm;
  http://www.qmi.com/registration/foodsafety/ISO22000/default.asp?language=english;
  http://www.foodsafety.uk.sgs.com/westbury_dairies_case_study-4.pdf;
  Faergemand and Jespersen, 2004;
  Pillay and Muliyil, 2005; Surak, 2003a).

1.2.7 ISO 22000 standard clauses

1 Scope

The scope focuses on control measures to be implemented to ensure that processes are in place to meet customer and regulatory food safety requirements. The types of organisations in the food chain to which this standard can be applied are the ones that are directly or indirectly involved in one or more steps of the food chain, regardless of the size or complicatedness of the organisation (Pillay and Muliyil, 2005).

2 Normative references

Normative reference deals with reference materials that can be used to determine definition associated with terms and vocabulary used in the ISO standard document (Pillay and Muliyil, 2005). Standards are encouraged to investigate the possibility of applying the most recent edition of the normative document indicated below. For undated references, the latest edition of the normative document referred to applies (Arvanitoyannis and Hadjicostas, 2001). Codex normative texts fall into three groups (FAO/WHO, 2005):

- the standards, usually related to product characteristics
- the code of practices, defining the production, processing, manufacturing, transport and storage practices that are essential to ensure the safety of food for consumption
- the guidelines, which can be principles that set out policy in certain key areas, or interpretative guidelines for the understanding of these principles or for the interpretation of the provisions of the Codex general standards (FAO, 2006).

3 Terms and definitions

In an attempt to maintain consistency and encourage the use of common terminology, the ISO 22000 standard terms and definitions section makes reference to the use of 82 definitions occurring in ISO 9000:2000 and lists definitions that are specific to this application. The rationale behind the definition section is to provide clarity of terminology and promote the use of a common language (Pillay and Muliyil, 2005).

3.1 Food safety

The basic food safety concept is this: food will not harm the consumer so long as intended use guidelines are followed when it is prepared or eaten. Conversely, food is potentially harmful whenever it has been exposed to hazardous agents and intended use guidelines have not been followed (http://www.praxiom.com/iso-22000-definitions.htm).

3.2 Food chain

Sequence of the steps and operations involved in the production, processing, distribution, storage and handling of a food and its ingredients, from primary production to consumption (ISO 22000:2005a).

3.3 Food safety hazard

Any biological, chemical or physical property that may cause a food to be unsafe for human consumption (http://a257.g.akamaitech.net/7/257/2422/14mar20010800/edocket.access.gpo.gov/cfr_2003/pdf/9CFR417.1.pdf).

3.4 Food safety policy
A food safety policy statement formally defines an organisation's commitment to food safety (see 3.1). It expresses, in general terms, what top management intends to do about food safety and describes the direction the organisation wishes to take. More precisely, a food safety policy statement should express an organisation's commitment to the implementation and ongoing maintenance of its FSMS. The food safety policy should drive the establishment of the FSMS and should also encourage people to update and improve its overall effectiveness (http://www.praxiom.com/iso-22000-definitions.htm).

3.5 End product
Product that will undergo no further processing or transformation by the organisation (ISO 22000:2005a).

3.6 Flow diagram
A diagram which identifies process steps, inputs and outputs (materials), sequential relationships (consecutive, feedback) and food safety controls (http://www.nzfsa.govt.nz/processed-food-retail-sale/fsp/haccp.pdf).

3.7 Control measure
Any action or activity that can be used to prevent or eliminate a food safety hazard (see 3.3) or reduce it to an acceptable level (http://www.codexalimentarius.net/download/standards/10087/CXC_057_2004e.pdf).

3.8 Prerequisite programme (PRP)
Describes all those activities other than specific HACCP plans, which affect food safety. Universal steps or procedures that control the operational activities within a food establishment allowing production of safe end food products (see 3.5). Managed and documented (Griffith, 2006).

3.9 Operational PRP
Operational prerequisite programmes (OPRPs) are prerequisite programmes (PRPs; see 3.8) that are essential. They are essential because a hazard analysis has shown that they are necessary in order to control specific food safety hazards (see 3.3). OPRPs are used to reduce the likelihood that products will be exposed to hazards, that they will be contaminated, and that hazards will proliferate. OPRPs are also used to reduce the likelihood that the processing environment will be exposed to hazards, that it will be contaminated, and that hazards will proliferate in that environment (http://www.praxiom.com/iso-22000-definitions.htm).

3.10 Critical control point (CCP)
A point in a step or procedure at which a control is to be applied to prevent or eliminate a hazard or reduce it to an acceptable level (PAHO, 2005).

3.11 Critical limit
The maximum or minimum value to which a physical, biological or chemical hazard should be controlled at a CCP to prevent, eliminate or reduce to an acceptable level the occurrence of the identified food safety hazard (http://a257.g.akamaitech.net/7/257/2422/14mar20010800/edocket.access.gpo.gov/cfr_2003/pdf/9CFR417.1.pdf).

3.12 Monitoring
Observations or measurements to assess whether control measures (see 3.7) at a critical point are being effectively implemented (http://www.qsae.org/web_en/pdf/HACCPImpGuide.pdf).

3.13 Correction
Action to eliminate a detected non-conformity (ISO 22000:2005a).

3.14 Corrective action
Remedial procedures to be followed when a deviation occurs. Action to be taken when the results of monitoring indicate a loss of control (http://www.nzfsa.govt.nz/processed-food-retail-sale/fsp/haccp.pdf).

3.15 Validation
Validation is the initial phase in which the plan is tested and reviewed. The choices made while working through the preliminary steps and HACCP principles should be repeatedly tested and shown to prevent or control identified hazards in the 'real world'. In this phase, microbial or residue testing can be effectively used to verify that the process is in control and is producing acceptable product. Such testing provides clear evidence that the techniques and methods adopted by the plant to control hazards are not just effective in theory but will work in this specific plant (USDA, 1999).

3.16 Verification
Application of methods, procedures, tests and other evaluations, in addition to monitoring to determine compliance with the HACCP plan (PAHO, 2005).

3.17 Updating
Immediate and/or planned activity to ensure application of the most recent information (ISO 22000:2005a).

4 Food safety management system (FSMS)

4.1 Establish a FSMS

In the food safety management system section, the emphasis is on establishing, documenting, implementing and maintaining an effective FSMS. This includes procedures and records required for ensuring effective development, implementing and updating the FSMS (Pillay and Muliyil, 2005). The organisation should:

- ensure that food safety hazards that may be reasonably expected to occur in relation to products within the scope of the system are identified, evaluated and controlled
- communicate appropriate information throughout the food chain
- communicate information concerning development, implementation, and updating FSMS, and
- evaluate periodically and update the FSMS (ISO 22000:2005a).

4.2 Document your FSMS

4.2.1 General

The operator shall ensure that all documents, records and data critical to the management of product quality and safety are in place and effectively controlled. All documents should be approved, signed and dated by appropriate authorised persons, and kept up-to-date; correct versions should be readily available to appropriate staff. No documents should be changed without authorisation (PAHO, 2005). Documentation enables communication of intent and consistency of action. Its use contributes to:

- achievement of conformity to customer requirements and food safety
- provision of appropriate training
- repeatability and traceability
- provision of objective evidence and
- evaluation of the effectiveness and continuing suitability of the FSMS
  (ISO 9000:2000).

The FSMS documentation includes:

- documented statements of the food safety policy and related objectives
- documented procedures and records (see 5.2) and
- documents to ensure the effective development, implementation and updating of the FSMS (ISO 22000:2005a).

4.2.2 Control of documents

Documents required by the FSMS are controlled by documented procedures, which provide for the:

- approval of documents for adequacy prior to issue
- review and update as necessary and re-approval of documents
- assurance that occurring changes and the current version status of documents are identified
- assurance that relevant versions of applicable documents are available at points of use
- assurance that documents remain legible and readily identifiable
- assurance that relevant documents of external origin are identified and their distribution controlled and
- prevention of the unintended use of obsolete documents and apply suitable identification to them if they are retained for any purpose (ISO 22000:2005a; http://www.qualitycouncil.com/samples/iso.pdf).

4.2.3 Control of records

Records should be established and maintained to provide evidence of conformity to requirements and of effective operation of the FSMS. Records should remain legible, readily identifiable and retrievable. A documented procedure shall be established to define the necessary controls for the identification, storage, protection, retrieval, retention time and disposition of records (Arvanitoyannis and Hadjicostas, 2001).

5 Management responsibility

5.1 Management commitment

Management responsibility outlines the commitment of top management to the implementation and maintenance of the FSMS (Fig. 1.8). Assigning a food safety system manager and team, setting clear policies, goals, emergency contingency plans and responsibilities, along with establishment of effective communication mechanisms within the organisation and with suppliers or customers are key elements of this clause. Regularly scheduled management reviews ensure that top management is made aware of the status of the system and that actions are authorised to correct nonconformities and continually improve the FSMS (Pillay and Muliyil, 2005).

Management should demonstrate their commitment to developing and improving their FSMS by:

- conducting regular management reviews
- establishing organisational objectives and food safety policies
- ensuring the availability of necessary resources and

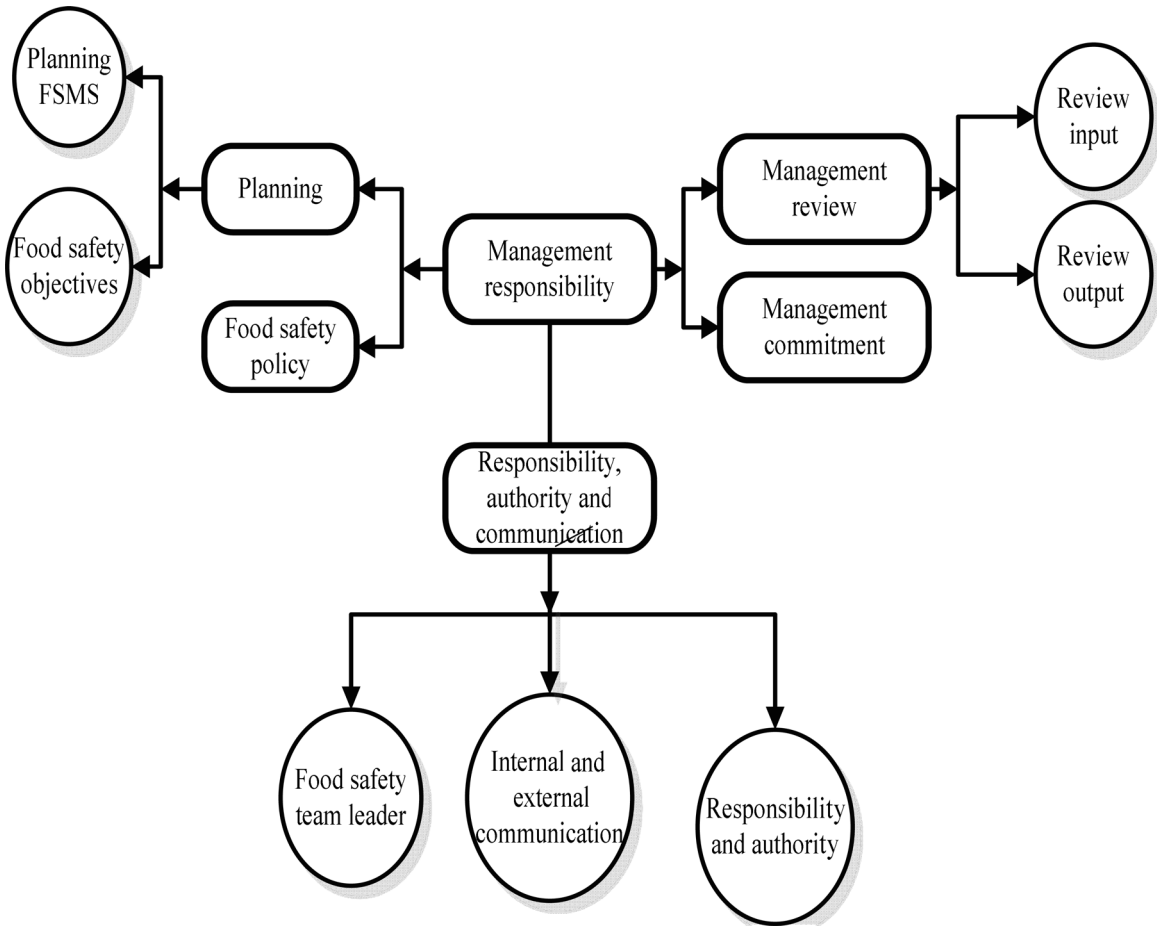

Fig. 1.8 Management responsibility. (Adapted from Arvanitoyannis and Hadjicostas, 2001; Tricker, 2001.)

- ensuring that everyone is aware of the importance of meeting customer, regulatory and legal requirements (Tricker, 2001).

Food safety management systems ensure that all food producers:

- comply with the requirements of relevant legislation
- identify all hazards and controls relating to their food business, e.g. temperature control, microbiological, chemical or physical contamination
- identify points in the food process that are critical to food safety and
- put in place control and monitoring procedures at these points (University of Sussex, 2006).

5.2 Establish food safety policy

The food safety intentions of top management need to be documented and communicated throughout the organisation. The requirement for the policy to be supported by measurable objectives should provide audit evidence of the effectiveness of the policy (IRCA, 2005). Top management should ensure that the food safety policy:

- is appropriate for the purpose of the organisation in the food chain
- conforms with statutory and regulatory requirements, and with agreed food safety requirements for the customers
- is communicated, implemented and maintained at all levels of organisation
- is reviewed for continuing suitability (see 5.8)
- addresses communication (see 5.6) and
- is supported by measurable objectives (ISO 22000:2005a).

5.3 Planning of FSMS
Top management should ensure that:

- planning of the FSMS is carried out towards meeting requirements explained in 4.1 as well as the objectives of the organisation that support food safety and
- the integrity of the FSMS is maintained when changes to the food safety management system are planned and implemented (http://www.bsiamericas.com/Food/Update/BackIssues/December2006.xalter).

5.4 Clarify your FSMS responsibilities and authorities
Top management should ensure that responsibilities and authorities are defined and communicated within the organisation to ensure the effective operation and maintenance of the FSMS. All personnel should have responsibility to report problems with the FSMS to identified person(s). Designated personnel should have defined responsibility and authority to initiate and record actions (ISO 22000:2005a).

5.5 Appoint a food safety team leader
A food safety team leader performs a similar role in an FSMS to that provided by the management representative in a Quality Management System (QMS) although the establishment of a food safety team of two or more people is also required. The team leader's role should be known throughout the organisation (IRCA, 2005). Top management appoints a food safety team leader who shall have the responsibility and authority:

- to manage a food safety team (see 7.3.2) and organise its work
- to ensure relevant training and education of the food safety team members (see 6.2.1)
- to ensure that the food safety management system is established, implemented, maintained and updated and
- to report to the organisation's top management on the effectiveness and suitability of the FSMS (http://www.bsiamericas.com/Food/Update/BackIssues/February2007.xalter).

5.6 Establish your communication
5.6.1 External communication
The organisation should establish, implement and maintain effective arrangements for communicating with:

- suppliers and vendors
- customers
- regulatory agencies
- non-governmental organisations
- the media and
- stockholders (Culley, 1998).

5.6.2 Internal communication
It is the responsibility of top management to facilitate the communication processes within the organisation (Fig. 1.9; Arvanitoyannis and Hadjicostas, 2001). Internal communication should be from the 'top down' – from the highest manager within the organisation down to the production worker who is at the heart of making the product (Culley, 1998). The food safety team should be informed including the following:

- products or new products
- raw materials, ingredients and services
- production systems and equipment
- production premises, location of equipment, surrounding environment
- cleaning and sanitation programmes
- packaging storage and distribution systems
- personnel qualification levels and/or allocation of responsibilities and authorisations
- statutory and regulatory requirements
- knowledge regarding food safety hazards and control
- customer, sector and other requirements that the organisation considers necessary
- relevant enquiries from external interested parties
- complaints indicating food safety hazards associated with the product and
- other conditions that have an impact on food safety and quality (ISO 22000:2005a; http://bis.org.in/sf/fad/FAD15(1681).pdf).

5.7 Emergency preparedness and response
A risk management approach will be normally adopted when implementing this clause, based on the risk of compromising food safety during emergency incidents. Auditors should be familiar with the concepts used to determine risk levels, taking into account such factors as incident severity, duration, likelihood of occurrence and the degree of control already in place. In addition to the identified risk levels, auditors should focus on the process for identifying risks and determining any necessary responses from a food safety standpoint (IRCA, 2005). Emergency situations may include, for example, fire, flooding, food contamination, poisoning, bio-terrorism, sabotage, energy failure, vehicle accidents and contamination of the environment (http://bis.org.in/sf/fad/FAD15(1681).pdf).

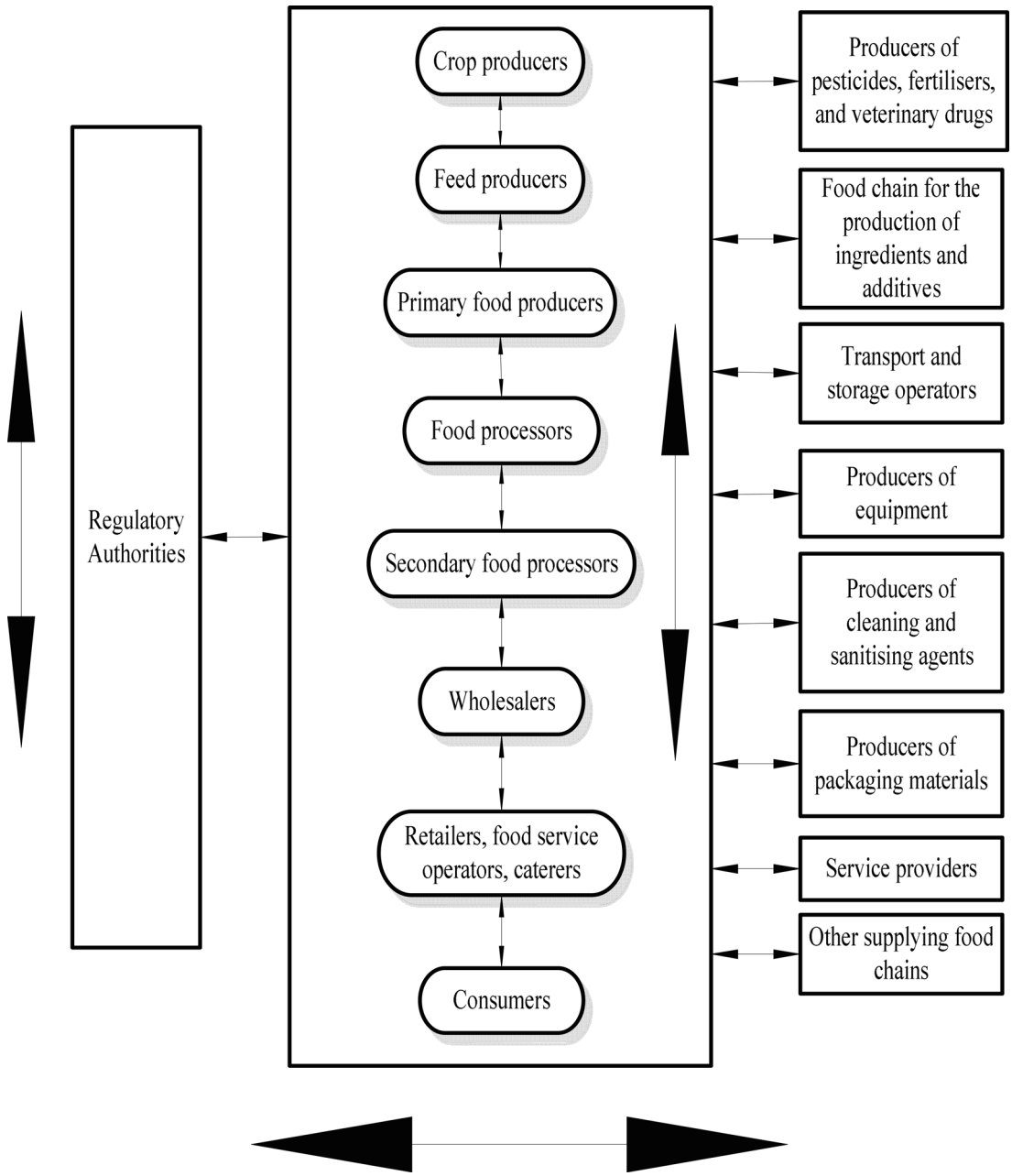

Fig. 1.9 Example for communication within the food chain (arrows indicate interactive communication; Faergemand and Jespersen, 2004; ISO 22000:2005a).

This requirement is also found in ISO 14001. The preparation for accidents or emergencies can be managed through:

- orientation of classes for new employees
- hazard evaluations
- emergency system evaluations and surveys
- training of the appropriate personnel
- staff or department meetings to keep personnel aware of their responsibilities and roles and
- emergency scenarios and the implementation of practice drills (Culley, 1998).

Response actions include all those activities that occur from the initial report of the incident through the decontamination and equipment clean-up phases of the incident. The focus of response actions is to stabilise, confine, contain and control the release of hazardous materials, transfer and recover materials, prevent unnecessary damage and stabilise the situation for the final clean-up operations (Ritchie and Hayes, 1998).

5.8 Review of management

5.8.1 General

Management shall review, at defined intervals, the continuing suitability and effectiveness of quality and safety management systems. This review shall include assessing opportunities for improvement and the need for changes to the quality and safety management systems (PAHO, 2005). Records from management reviews should be maintained (see 4.2.3) (Arvanitoyannis and Hadjicostas, 2001).

5.8.2 Review input

The input to management review should include current performance and improvement opportunities related to the following:

- results of external audits or inspections
- customer feedback (see 5.6.1)
- emergency situations, accidents (see 5.7) and withdrawals (see 7.10.4)
- analysis of results of verification activities (see 8.4.3)
- follow-up actions from previous management reviews
- changes possibly affecting the FSMS (see 5.6.2) and
- reviewing results of system updating activities (see 8.5.2) (ISO 22000:2005a; Tricker, 2001).

5.8.3 Review output

The output from the management review should include decisions and actions related to:

- assurance of the food safety (see 4.1)
- improvement of FSMS effectiveness (see 8.5)
- resource needs (see 6.1) and
- revisions of the organisation's food safety policy and related objectives (see 5.2; ISO 22000:2005a).

6 Resources management

6.1 Providing of adequate resources

An effectively implemented FSMS requires that top management provide adequate resources, budgets and personnel to effectively run the system (Fig. 1.10). Scheduled, documented training and evaluations of key personnel and provision of a safe work environment and infrastructure are crucial to the continuity of system. This section is addressed under resource management (Fig. 1.11; Pillay and Muliyil, 2005).

6.2 Provide adequate human resources

6.2.1 General

The food safety team and other personnel carrying out activities having an impact on food safety should be competent and have appropriate education, training, skills and experience. Where the assistance of external experts is required for the development, implementation, operation or assessment of the FSMS, records of agreement or contracts defining the responsibility and authority of experts should be available (ISO 22000:2005a).

6.2.2 Competence, awareness and training

The organisation is responsible for ensuring that all personnel are trained and experienced to the extent necessary to undertake their assigned activities and responsibilities effectively. Thus, whenever training needs have been identified, top management should endeavour to make the relevant training available and full records should be maintained of all training undertaken by employees (Tricker, 2001).

The organisation should:

- determine the necessary competencies for personnel performing work affecting food safety
- provide training
- assess the effectiveness of the actions taken
- make sure its personnel are aware of their activities and its importance for the achievement of the food safety objectives and
- keep appropriate records of training, skills and experience (Arvanitoyannis and Hadjicostas, 2001).

6.3 Provide adequate infrastructure

The organisation shall determine, provide and maintain the required infrastructure for:

- workplace and associated facilities
- process equipment (both software and hardware) and
- supporting services (such as transport or communication; Arvanitoyannis and Hadjicostas, 2001; http://www.qualitycouncil.com/samples/iso.pdf).

6.4 Provide adequate work environment

The organisation identifies and manages the human factors (e.g. work methodologies, achievement and

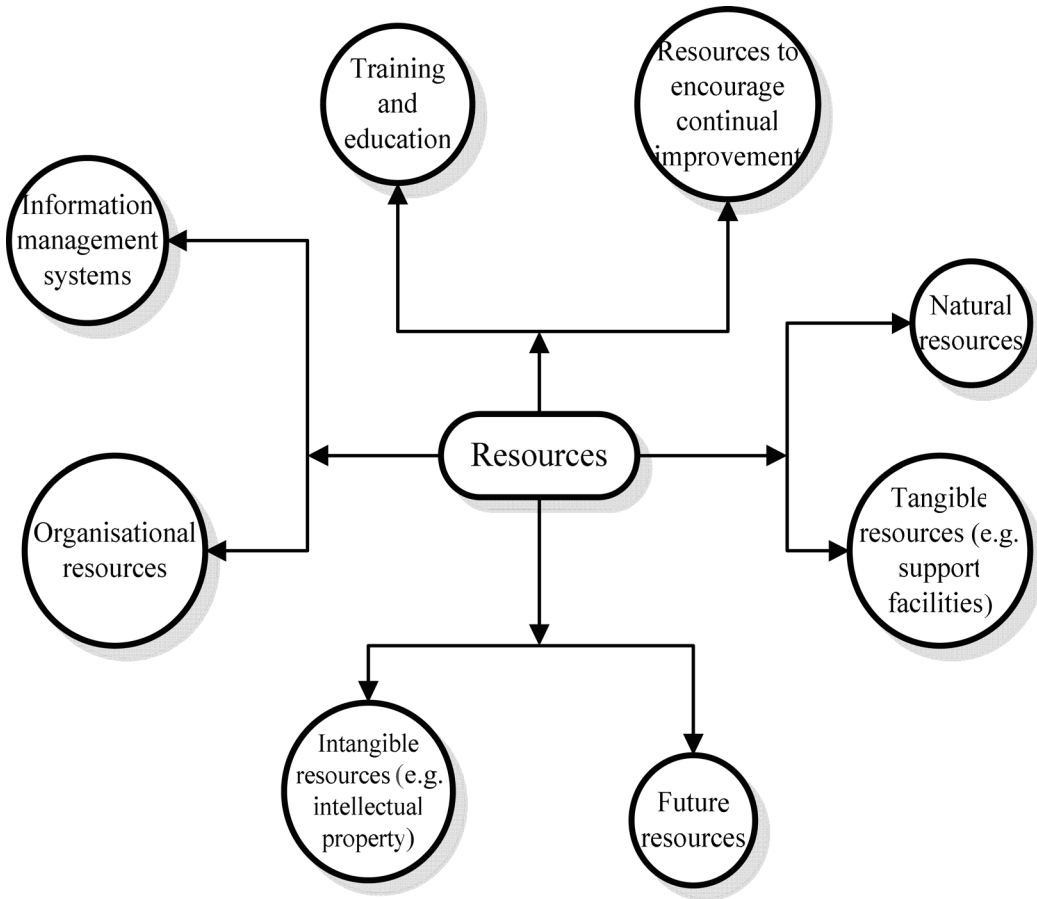

Fig. 1.10 Various types of resources (adapted from Tricker, 2001).

involvement opportunities, safety rules and guidance, ergonomics etc.) and physical factors (e.g. light, hygiene, vibration, noise, humidity, pollution, heat, cleanliness and air flow) of the work environment needed to achieve conformity of the product (http://www.qualitycouncil.com/samples/iso.pdf; Tricker, 2001).

7 Planning and realisation of safe product

7.1 General

Planning and realisation of safe products incorporate the elements of GMP and HACCP, including any regulatory requirements applicable to the organisation and processes. Adequate prerequisite programmes (e.g. training, sanitation, maintenance, traceability, supplier review, control of non-conforming product and recall procedures) are required that address general requirements to provide a foundation for the production of safe food (Fig. 1.12; Pillay and Muliyil, 2005).

7.2 Establish prerequisite programmes (PRPs)

Basic prerequisite programmes should be in place to:

- protect products from contamination by biological, chemical and physical food safety hazards
- control bacterial growth that can result from temperature abuse and
- maintain equipment (FDA, 2006).

The existence and effectiveness of prerequisite programmes should be assessed during the design and implementation of each HACCP plan. All prerequisite programmes should be documented and regularly

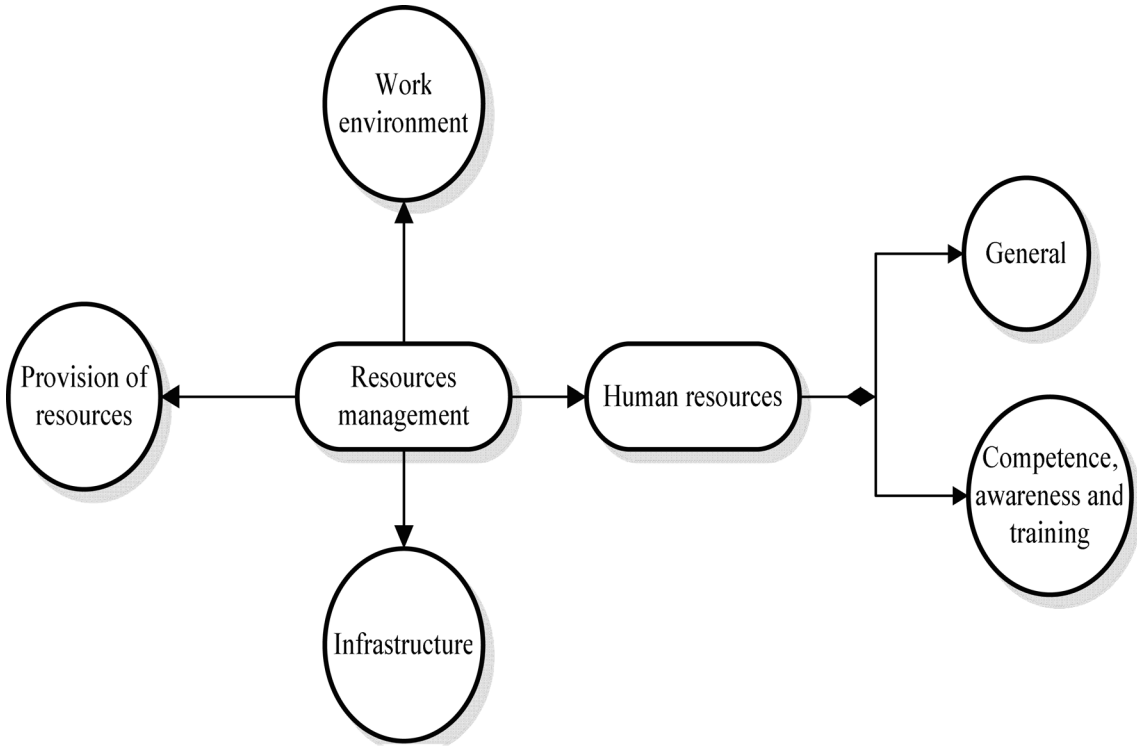

Fig. 1.11 Resource management (Arvanitoyannis and Hadjicostas, 2001; Tricker, 2001).

audited. Prerequisite programmes are established and managed separately from the HACCP plan (FDA/USDA/NACMCF, 1997). A tree diagram of prerequisite programmes according to ISO 22000 is presented in Fig. 1.13.

PRPs should:

- be appropriate to organisation's needs with regard to food safety
- be appropriate to the size and type of the operation, and the nature of products being manufactured and/or handled
- be implemented to the entire production system and
- be approved by the food safety team
(ISO 22000:2005a).

7.3 Primary levels of hazard analysis materialisation

7.3.1 General

The origin of the raw materials, ingredients and product contact materials should be taken into account when they might impact on the evaluation of the occurrence of hazards and the levels of these hazards. The information to be taken into account may be different from the original information required to maintain traceability (ISO 22000:2005b).

7.3.2 Food safety team

In addition to the final resources needed to fund a team of competent managers and specialists, it may prove difficult to find appropriate training and recruit experts. Nevertheless, an organisation can find a solution such as:

- exchanging or sharing HACCP team members
- integrating supplier or client experts into the team and
- using e-learning when the required vocational training is not available in appropriate timeframes, locations or quality
(Blanc, 2006).

7.3.3 Product characteristics

7.3.3.1 Raw materials, ingredients and product-contact materials

All raw materials, ingredients and product-contact materials shall be described in documents as appropriate:

- biological, chemical and physical characteristics
- composition of formulated ingredients, including additives and processing aids

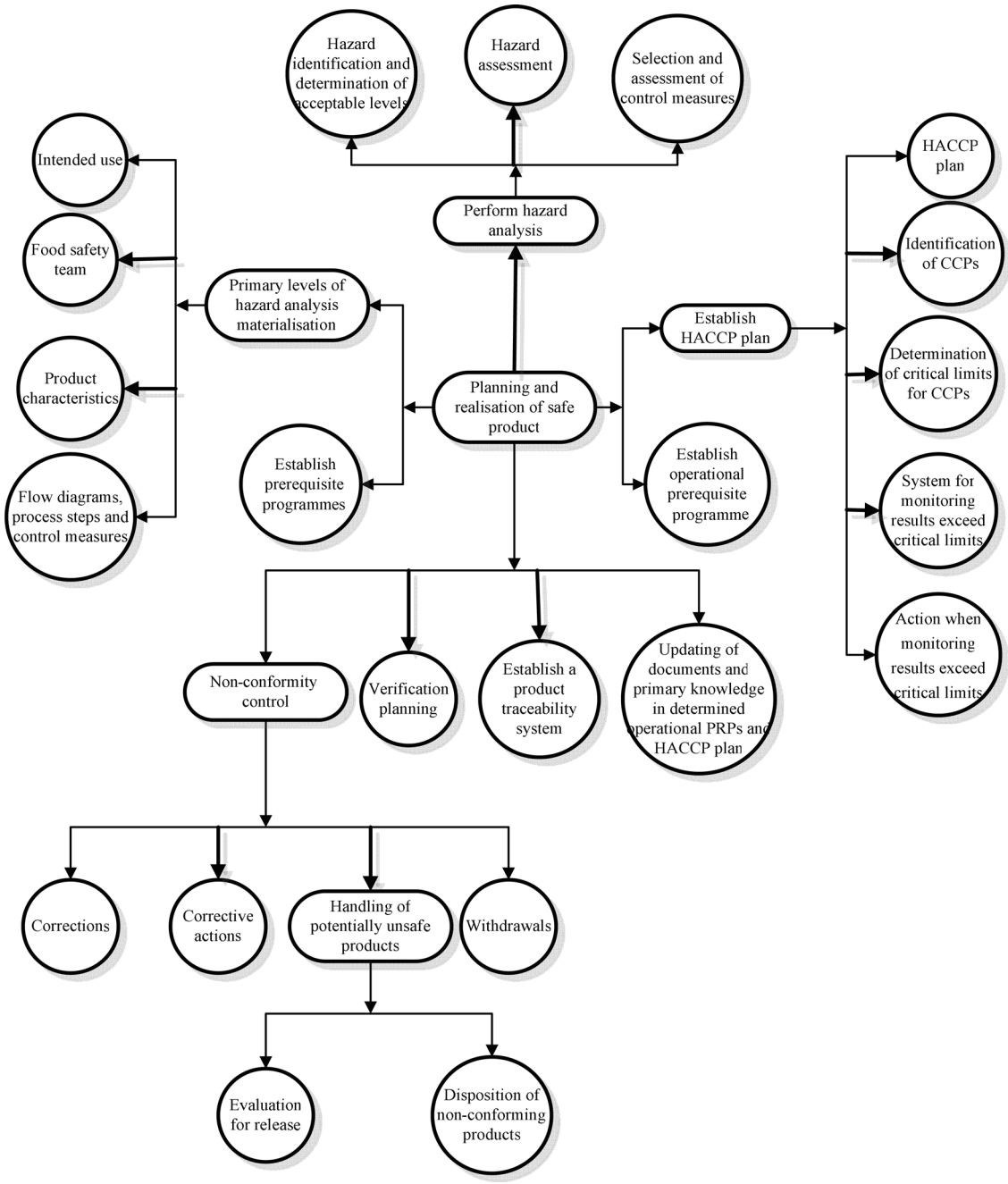

Fig. 1.12 Planning and realisation of safe product (Arvanitoyannis and Hadjicostas, 2001; Tricker, 2001).

- origin
- method of production
- packaging and delivery methods
- storage conditions and shelf life
- preparation and/or handling before use or processing and
- food safety-related acceptance criteria or specifications of purchased materials and ingredients appropriate

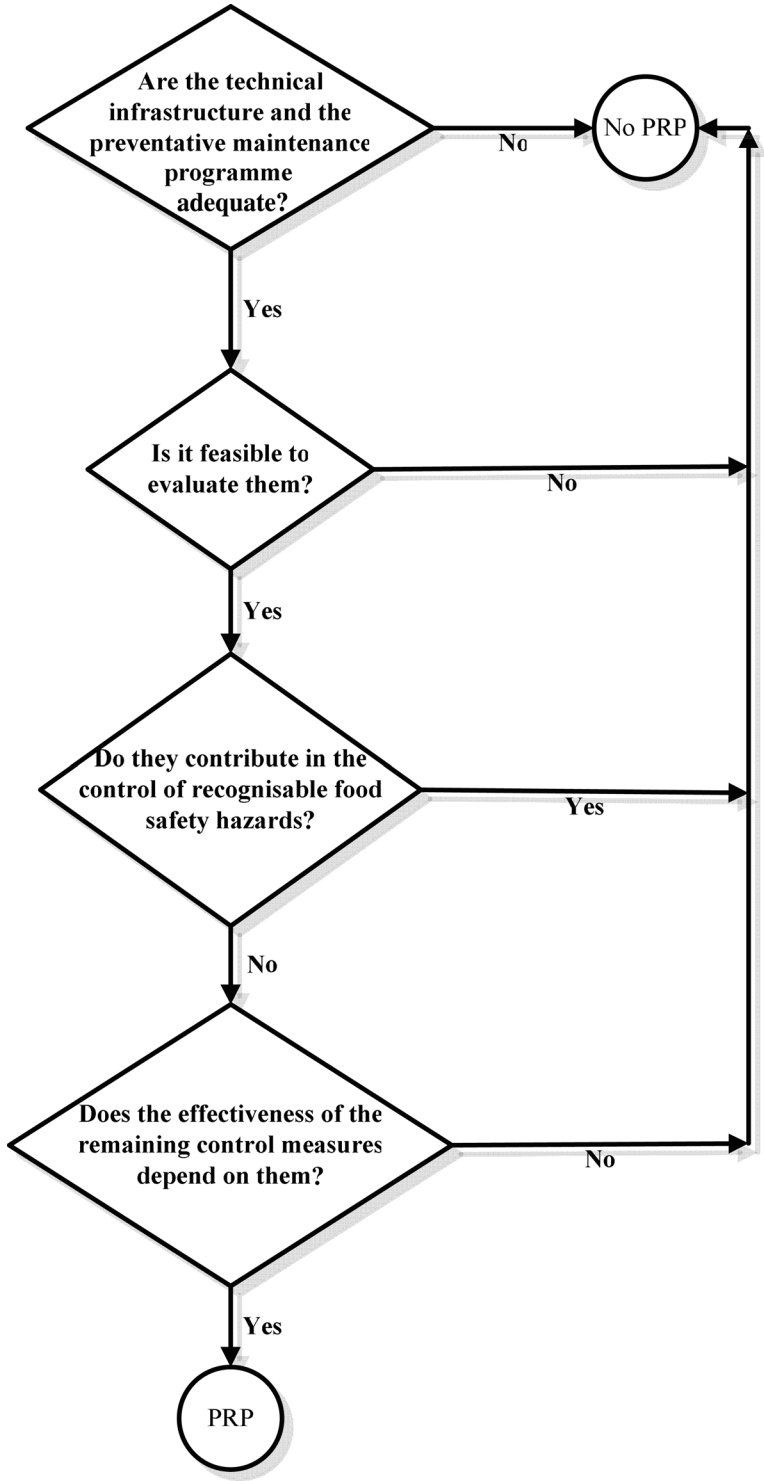

Fig. 1.13 Tree diagram for determination of prerequisite programmes according to ISO 22000.

to their intended uses (http://bis.org.in/sf/fad/FAD15 (1681).pdf; ISO 22000:2005a).

7.3.3.2 Characteristics of end products
Characteristics of end products should be described including the following information:

- product name or similar identification
- composition
- biological, chemical and physical hazard specification
- intended shelf life and storage conditions
- packaging labelling relating to food safety and/or instructions for handling, preparation and usage and
- methods of distribution
(ISO 22000:2005a).

7.3.4 Intended use
Intended use should indicate whether the product is to be sold at retail, to food service or as an ingredient for another food item (Harris, 1999). The HACCP team should specify where the product will be sold, as well as the target group, especially if it happens to be a sensitive portion of the population (i.e. elderly, immune-suppressed, pregnant women, and infants; FAO, 1998).

7.3.5 Flow diagrams, process steps and control measures

7.3.5.1 Flow diagrams
Flow diagrams should be clear, accurate and sufficiently detailed. Flow diagrams should include the following:

- the sequence and interaction of all steps in the operation
- any outsourced processes and subcontracted work
- where raw materials, ingredients and intermediate products enter the flow
- where reworking and recycling take place by products
- where end products, intermediate products and waste are released or removed and
- pH and water activity during processing of food
(http://bis.org.in/sf/fad/FAD15(1681).pdf; ISO 22000: 2005a).

7.3.5.2 Description of process steps and control measures
The existing control measures should be described to the extent needed to conduct the hazard analysis (see 7.4). External requirements (e.g. from regulatory authorities or customers) that may impact the choice and the rigorousness of the control measures should also be described. The requirements should be described (ISO 22000:2005a).

7.4 Carry out hazard analysis
7.4.1 General
The hazard analysis for a specific food consists of a systematic evaluation of all raw materials, ingredients and production steps; identification of hazards that are likely to occur; and consideration of control or preventive measures for hazards (Corlett, 1998).

7.4.2 Hazard identification and determination of acceptable levels
Food safety hazards identification should be based on:

- preliminary information and data collected (see 7.3)
- experience
- external information (epidemiological and other historical data) and
- information from the food chain on food safety hazards that may be of relevance for the safety of the end products, intermediate products and the food at consumption (ISO 22000:2005a).

The acceptable level in the end product should be determined through:

- objectives, targets or end product criteria established by statutory and regulatory authorities
- specifications or other information communicated by the organisation representing the subsequent step in the food chain and
- the maximum levels found by the food safety team taking into account acceptable levels agreed on with the customer and/or according to law, scientific literature and professional experience (ISO 22000:2005b).

7.4.3 Hazard assessment
Hazard assessment serves to determine which of the potential hazards identified require specific control measures. To ensure such control, the standard requires the selection of (or combination of) control measures (see 7.4.4; Blanc, 2006). In conducting the hazard assessment, the following should be taken into consideration:

- the sources of the hazard
- the probability of occurrence of the hazard
- the nature of the hazard and
- the severity of the adverse health effects that can be caused by the hazard
(ISO 22000:2005b).

7.4.4 Selection and assessment of control measures
The selection and categorisation of control measures should be carried out according to:

- the effect on identified food safety hazards
- the feasibility for monitoring
- the place within the system relative to other control measures
- the likelihood of failure or significant processing variability
- the severity of the consequences in case of failure
- whether the control measure is established and applied to eliminate or reduce hazards and
- synergistic effects
(ISO 22000:2005a).

The following may guide the organisation in the categorisation process:

- the impact of a control measure on the hazard level (the higher impact there is, the more likely the control measure belongs to the HACCP plan)
- the severity on consumer health of a hazard that the measure is selected to control (the more severe it is, the more likely it belongs to the HACCP plan) and
- the need for monitoring (the more pressing the need, the more likely it belongs to the HACCP plan)
(ISO 22000:2005b).

7.5 Establish operational prerequisite programmes
One of the outputs of the hazard analysis is the determination of operational PRPs. This sets up prevention and control measures which deal with food safety risk levels somewhat below those which need to be included in the HACCP plan. Auditors should examine the decision-making process at the hazard analysis stage as well as how the necessary control and monitoring activities for operational PRPs are determined (IRCA, 2005). The operational PRPs should include the following information for each programme:

- food safety hazards to be controlled (see 7.4.4)
- control measures (see 7.4.4)
- monitoring procedures that demonstrate that operational PRPs are implemented
- corrections and corrective actions if operational PRPs are not in control (see 7.10.1 and 7.10.2, respectively)
- responsibilities and authorities and
- records of monitoring
(ISO 22000:2005a; http://bis.org.in/sf/fad/FAD15(1681).pdf).

7.6 Establish HACCP plan
7.6.1 HACCP plan
The initial focus of the HACCP coordinator and the team is the development of the HACCP plan or plans for specific food products (Corlett, 1998). On the identification of the highest risks to food safety within the hazard analysis, the HACCP plan becomes the blueprint for their control in the production/processing/service processes being audited. The auditor does not need to be a HACCP expert but can evaluate the process from decision making in the hazard analysis through the determination of control parameters including identification of critical control points (CCPs). Given the importance of this methodology to the FSMS, the auditor should allocate a good proportion of the audit duration to its evaluation (IRCA, 2005). The HACCP plan should include the following information for each identified CCP:

- food safety hazards to be controlled at CCP (see 7.4.4)
- control measures (see 7.4.4)
- critical limits (CLs; see 7.6.3)
- monitoring procedures (see 7.6.4)
- corrections and corrective actions if critical limits are not in control (see 7.6.5)
- responsibilities and authorities and
- records of monitoring
(ISO 22000:2005a).

7.6.2 Identification of CCPs
CCPs may be located at any point in the food production and manufacturing system for a food product where hazards need to be either prevented, eliminated or reduced to acceptable levels (Corlett, 1998). The identification of CCPs has two consequences for the HACCP team which should then:

- ensure that appropriate control measures are effectively designed and implemented. In particular, if a hazard has been identified at a step where control is necessary for product safety and no control measure exists at that step, then the product or process should be modified at that step or at an earlier or later stage, to include a control measure, and
- establish and implement a monitoring system per critical point (Commission of the European Communities, 2005).

CCPs should be carefully identified and documented. They should be used only for purposes of product safety or where use should be justified by the critical nature of the CCP. CCPs should not be confused with control points that do not control safety but refer to quality issues (Corlett, 1998).

7.6.3 Determination of critical limits for CCPs
The establishment of critical limits succeeds the identification of all factors associated with CCPs. Scientifically determined critical limits levels are established for all the identified factors and components causing an unacceptable consumer health risk (Arvanitoyannis and Hadjicostas, 2001).

7.6.4 System for monitoring results exceed critical limits
Most monitoring procedures for CCPs should provide real-time information related to on-line processes. Furthermore, monitoring should provide this information in time to make adjustments to ensure control of the process to prevent violating the critical limits. Therefore, there may not be time for lengthy analytical testing. Physical and chemical measurements that give information about the degree of microbiological control are often preferred to microbiological testing because they can be done rapidly (ISO 22000:2005b). The monitoring system should consist of procedures, instructions and records that cover:

- measurements or observations
- monitoring devices
- calibration methods (see 8.3)
- monitoring frequency
- responsibility and authority related to monitoring and evaluation of monitoring results and
- record requirements and methods
(ISO 22000:2005a).

7.6.5 Action when monitoring results exceed critical limits
The critical limits are set at a point where the products become unsafe. In practice, therefore, it is common to work against limits that give an early warning that a process might become out of control. The organisation may choose whether any actions are going to be taken when exceeding warning limits (ISO 22000:2005b).

7.7 Updating of documents and primary knowledge in determined operational PRPs and HACCP plan
The organisation should update the operational PRPs and HACCP plan, if necessary:

- product characteristics (see 7.3.3)
- intended use (see 7.3.4)
- flow diagrams (see 7.3.5.1)
- process steps (see 7.3.5.2) and
- control measures (see 7.3.5.2)
(ISO 22000:2005a).

7.8 Verification planning
This clause sets in place those monitoring arrangements at the process level which are designed to provide assurance that the FSMS is performing effectively on a daily basis. The food safety team is involved in result evaluation (see 8.4.2) and failures are to be dealt with through the potentially unsafe product disposition process (see 7.10.3). As with several other sections of the standard, this clause is best audited as part of a process audit of the verification processes in the FSMS (IRCA, 2005). The verification activities should confirm that:

- PRPs are properly implemented (see 7.2)
- input to the hazard analysis (see 7.3) is continually updated
- operational PRPs (see 7.5) and HACCP plan (see 7.6.1) are implemented and effective
- hazard levels are within the acceptable levels (see 7.4.2) and
- other procedures required by the organisation are implemented and effective (ISO 22000:2005a).

7.9 Establish a product traceability system
A traceability system is mandatory in ISO 22000 but happens to be a common process in the food industry, often as a result of legislation. The auditor should check the batch and/or lot identification in records maintained throughout the process from material receipt to end product dispatch. Note that the organisation needs to define a retention period for traceability records which is related to system assessment and considers the implications for disposition of potentially unsafe products and product withdrawal (IRCA, 2005).

7.10 Non-conformity control
7.10.1 Corrections
The organisation should ensure that product which does not conform to product requirements is identified and controlled to prevent its unintended use or delivery. The controls and related responsibilities and authorities for dealing with non-conforming product shall be defined in a documented procedure (ISO 9001:2000). A documented procedure should be established and maintained defining:

- the identification and assessment of affected end products to determine their proper handling (see 7.10.3) and
- a review of corrections carried out (ISO 22000:2005a).

When non-conforming product is corrected, it shall be subject to re-verification to demonstrate conformity

to the requirements. When non-conforming product is detected after delivery or use has started, the organisation shall take action appropriate to the effects, or potential effects, of the non-conformity (ISO 9001: 2000).

7.10.2 Corrective actions
Once the non-conformance has been identified, the next step is to initiate the corrective action process (Culley, 1998). A documented procedure shall be established to define requirements for:

- reviewing non-conformities (including customer complaints)
- determining the causes of non-conformities
- evaluating the need for action to ensure that non-conformities do not recur
- implementing corrective action required
- recording results of action taken (see 4.2.4) and
- reviewing corrective action taken
  (Tricker, 2001).

7.10.3 Handling of potentially unsafe products

7.10.3.1 General
The organisation should deal with non-conforming product by one or more of the following ways:

- by taking action to eliminate the detected non-conformity
- by authorising its use, release or acceptance under concession by a relevant authority and, where applicable, by the customer
- by taking action to preclude its original intended use or application
  (ISO 9001:2000).

7.10.3.2 Evaluation for release
Each lot of product affected by the non-conformity should be released as safe when:

- there is an evidence that the control measures have been effective
- there is evidence that the combined effect of the control measures for that particular product complies with the performance intended (see 7.4.2) and
- the results of sampling, analysis and/or other verification activities demonstrate that the affected lot of product complies with the acceptable levels for the food safety hazards concerned
  (ISO 22000:2005a).

7.10.3.3 Disposition of non-conforming products
Following evaluation, if the lot of product is not acceptable for release it shall be handled by one of the following activities:

- reprocessing or further processing within or outside the organisation to ensure that the food safety hazard or parameters not within specified limit, are eliminated or reduced to acceptable levels and
- destruction and/or disposal as waste. Inadvertent use of such material shall be prevented (http://bis.org.in/sf/fad/FAD15(1681).pdf).

7.10.4 Withdrawals
To enable and facilitate the complete and timely withdrawal of lots of end products which have been identified as unsafe:

- top management should appoint personnel having the authority to initiate a withdrawal and personnel responsible for executing the withdrawal and
- the organisation should establish and maintain a documented procedure for:
  (a) notification to relevant interested parties (e.g. statutory and regulatory authorities, customers and/or consumers)
  (b) handling of withdrawn products as well as affected lots of the products still in stock and
  (c) the sequence of actions to be taken (http://bis.org.in/sf/fad/FAD15(1681).pdf; ISO 22000:2005a).

8 Validation, verification and improvement of FSMS

8.1 General
In order to maintain and demonstrate the effectiveness of the FSMS, the organisation should validate that all assumptions used within the system are scientifically sound. In addition, the organisation should plan, conduct and document regular verification of all components of the system to evaluate whether or not the system is operating as designed or if modifications are needed. The verification should also form part of a continual improvement process whereby the organisation reviews verification. This section is covered under validation, verification and improvement of the FSMS (Fig. 1.14; Pillay and Muliyil, 2005).

8.2 Validation of food safety control measure combinations
Validation of control measure combinations, basically a new requirement introduced by ISO 22000 that relates to the control measures addressing hazards having been assessed as needing control, control measures that should then be validated before being

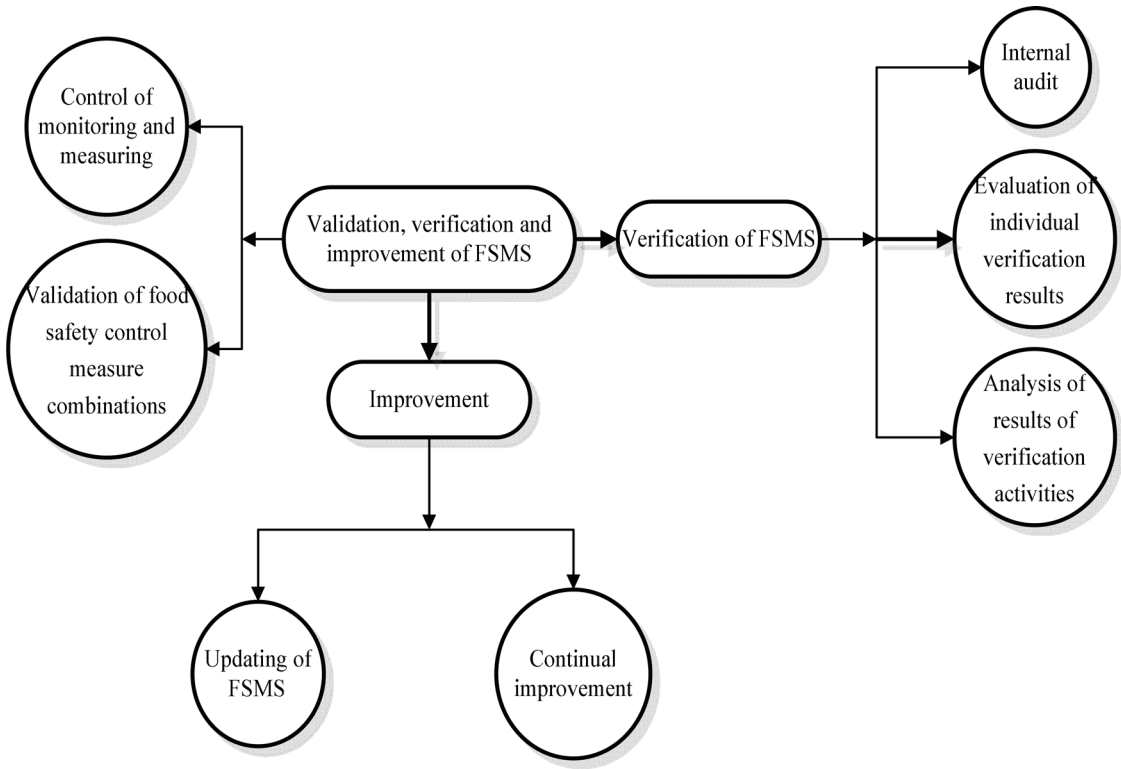

Fig. 1.14 Validation, verification and improvement of FSMS (Arvanitoyannis and Hadjicostas, 2001; Tricker, 2001).

implemented (Blanc, 2006). Steps prior to validation include:

- identify the food safety hazards that are intended to be controlled
- identify the food safety outcome required
- identify the necessary control measures and determine which are to be validated
- identify whether the control measure has previously been appropriately validated or whether its performance is so well established for the application and
- if necessary, prioritise control measures to be validated (FAO/WHO, 2006b).

The organisation should validate (see 3.15) that:

- the selected control measures are capable of achieving the intended control of food safety hazards and
- the control measures are effective and capable of ensuring control of the identified food safety hazards to obtain end products that meet the defined acceptable levels
(ISO 22000:2005a).

8.3 Control of monitoring and measuring

This clause addresses the need for known accuracy of measuring equipment and aligns with the corresponding requirement in ISO 9001. Note that it applies only to monitoring and measuring of parameters used in the FSMS in relation to food safety. Standards used for calibration should reflect the way the equipment is used (IRCA, 2005). Where necessary to ensure valid results, measuring equipment should be:

- calibrated or verified at specified intervals against international or national measurement standards
- adjusted or re-adjusted
- identified to enable the calibration status to be determined
- safeguarded from adjustments that would impair the measurement and
- properly handled, maintained and stored
(Arvanitoyannis and Hadjicostas, 2001).

8.4 Verification of FSMS

8.4.1 Internal audit

The organisation should audit those systems and procedures, which are critical to product safety, legality

and quality, to ensure they are in place, appropriate and complied with (http://www.pasa.doh.gov.uk/food/docs/code_of_practice_2001.pdf). Each procedure is audited separately, products are audited, processes are audited and records are audited. All of these audits are planned out only as far as the next audit – the frequency is varied to suit the level of confidence in the area being audited. Because the audits are small, less trained staff can be used, and this in turn reduces the negative connotations of an internal audit (since now almost anyone can be used as an auditor). Periodically, a full internal audit is carried out to ensure that the overall system still complies with the standard (deBeer, 1993). The schedule for conducting internal audits shall be documented and include planning, reports and improvements. The detailed auditing programme should include as a minimum:

- preparation and issuing of audit plans
- scope of the audits
- frequency of the audits
- methods for conducting the audits
- reporting of findings
- distribution of reports
- implementation of corrective actions and follow-up activities and
- selection and training of competent auditors (PAHO, 2005).

The organisation shall conduct internal audits at planned intervals to determine whether the FSMS:

- complies with the planned arrangements, to the FSMS requirements established by the organisation, and to the requirements of this International Standard and
- is effectively implemented and maintained (Arvanitoyannis and Hadjicostas, 2001).

8.4.2 Evaluation of individual verification results
If verification does not demonstrate conformity with the planned arrangements, the organisation should take action to achieve the required conformity. Such actions should review:

- existing procedures and communication channels (see 5.6 and 7.7)
- conclusions of the food safety hazard analysis (see 7.4), established operational PRPs (see 7.5) and HACCP plan (see 7.6.1)
- PRPs (see 7.2) and
- effectiveness of human resource management and training activities (see 6.2; ISO 22000:2005a).

8.4.3 Analysis of results of verification activities
Verification activities are carried out by individuals within a company, third-party experts and regulatory agencies. It is important that individuals doing verification have appropriate technical expertise to perform this function (microhttp://www.nzfsa.govt.nz/processed-food-retail-sale/fsp/haccp.pdf). The assessor should consider what, how, when and by whom the verification procedures have been undertaken, and whether these are adequate and effective. This may be indicated by an assessment of the validation data, sampling results, internal and external audit documentation as well as the frequency and thoroughness of all verification activities (Motarjemi, 2000). The analysis of results of verification activities should be carried out in order:

- to confirm that the overall performance of the system meets the planned arrangements and FSMS requirements
- to identify the need for updating or improving the FSMS
- to identify trends that indicate a higher incidence of potentially unsafe products
- to establish information for planning of the internal audit and
- to provide evidence that any corrections and corrective actions are effective (ISO 22000:2005a).

8.5 Improvement
8.5.1 Continual improvement
By conducting routine internal audits and monitoring, it will become evident that the policy, objectives, targets and plans will have to be modified. Continual improvement is not really a last step but an integral part of every step in environmental management whether it is mentioned or not (Lee Kuhre, 1995). Actions for improvement include the following:

- analysing and evaluating the existing situation to identify areas for improvement
- establishing the objectives for improvement
- searching for possible solutions to achieve the objectives
- evaluating these solutions and making a selection
- implementing the selected solution
- measuring, verifying, analysing and evaluating results of the implementation to determine that the objectives have been met and
- formalising changes (ISO 9000:2000).

Management should ensure that the organisation continually improves the effectiveness of the FSMS through:

- communication (see 5.6)
- management review (see 5.8)
- internal audit (see 8.4.1)
- evaluation of individual verification results (see 8.4.2)
- analysis of results of verification activities (see 8.4.3)
- validation of control measure combinations (see 8.2)
- corrective actions (see 7.10.2) and
- FSMS updating (see 8.5.2)
(ISO 22000:2005a).

8.5.2 Updating of FSMS

Frequently upgrading the entire system will keep it cost-effective and impacts will be reduced to the maximum extent possible (Lee Kuhre, 1995). This clause involves the food safety team in a pre-planned periodic evaluation of the currency of the information used in the FSMS (refer to Definition 3.17). Allied with the lower level updating in Clause 7.7, the results of this evaluation feed into the management review (Clause 5.8.2). Auditors should check whether the scope of this evaluation covers the whole FSMS starting with the issues which trigger an update through to the successful implementation of the change (IRCA, 2005). The evaluation and updating activities should be based on:

- input from communication (external and internal; see 5.6)
- input from other information concerning the suitability, adequacy and effectiveness of the FSMS
- output from the analysis of results of verification activities (see 8.4.3)
- output from management review (see 5.8.3; ISO 22000:2005a).

ABBREVIATIONS

CCPs	Critical control points
CIAA	Confederation of Food and Drink Industries of the EU
CLs	Critical limits
EMAR	Eco-Management and Audit Regulation
EMS	Environmental management system
FDA	Food and Drug Administration
FMEA	Failure, mode and effect analysis
FMI	Food Marketing Institute
FSIS	Food Safety and Inspection Services
FSMS	Food safety management system
GATT	General Agreement on Tariffs and Trade
GFSI	Global Food Safety Initiative
GMPs	Good manufacturing practices
HACCP	Hazard Analysis and Critical Control Points
ISO/TS	ISO Technical Specification
MF	Microfiltration
NF	Nanofiltration
OPRPs	Operational prerequisite programmes
PRPs	Prerequisite programmes
QMS	Quality management system
RO	Reverse osmosis
SLDBs	Small and/or less developed businesses
TBT	Technical Barriers to Trade
TQM	Total quality management
TQS	Total quality system
UF	Ultrafiltration
WTO	World Trade Organisation

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2
A Summary of EU, US and Canadian Legislation Relating to Safety in Foods of Animal Origin

Ioannis S. Arvanitoyannis and Persefoni Tserkezou

2.1 INTRODUCTION

Fundamentals of the science and technology are associated with harvesting, processing, packaging, preservation, storage, distribution, marketing and safety of food products of commerce (http://www.fst.vt.edu/undergraduate.courses.html). Milk and milk products for import into the European Union (EU) must fulfil certain basic animal health criteria. This ensures that milk and a milk product also conform to the animal health requirements laid down in legislation and is intended to safeguard animal health in the EU. Legislation lays down sensory attributes of milk and dairy products important in evaluation and judging product quality. It is also related to production and processing methods affecting milk and dairy product quality as determined by organoleptic evaluation (http://europa.eu.int/comm/food/animalproducts/milk/index_en.htm).

> "Examination of animals before slaughtering; diseased animals slaughtered separately and carcasses examined. For the purpose of preventing the use in commerce of meat and meat food products which are adulterated, inspectors appointed for that purpose, an examination and inspection of all cattle, sheep, swine, goats, horses, mules and other equines before they shall be allowed to enter into any slaughtering, packing, meat-canning, rendering or similar establishment, in which they are to be slaughtered and the meat and meat food products thereof are to be used in commerce; and all cattle, sheep, swine, goats, horses, mules and other equines found on such inspection to show symptoms of disease shall be set apart and slaughtered separately from all other cattle, sheep, swine, goats, horses, mules or other equines, and when so slaughtered the carcasses of said cattle, sheep, swine, goats, horses, mules or other equines shall be subject to a careful examination and inspection, all as provided by the rules and regulations to be prescribed by the Secretary (http://www .washingtonwatchdog.org/documents/usc/index.html)."

The 'fork-to-farm' philosophy underlines the fact that the quality and safety of food for those who eat it is a major priority for the industry. Research is focused on making food as safe and clean as possible. However, these high standards may not be easy to meet in other parts of the world (http://wyomcases.courts.state.wy.us/applications/oscn/DeliverDocument.asp?CiteID=205731).

2.2 EU LEGISLATION FOR FOOD OF ANIMAL ORIGIN

2.2.1 Controls and food hygiene rules

The Directive 85/591/EEC (entry into force 23/12/1987) claims that the sampling and analysis are necessary because of the following criteria: (a) the need to ensure that Community law is uniformly applied, (b) the existence of barriers to intra-Community trade and (c) the permanent or recurrent nature of the criteria. The Directive shall take account of the state of scientific and technical knowledge, in particular of proven methods of sampling and analysis. The introduction of the measures shall not preclude Member States from using other tested and scientifically valid methods provided that this does not hinder the free movement of products recognised as complying with the rules by virtue of Community methods. The methods of analysis introduced shall comply with the criteria set out above. Where a Member State has detailed evidence that a measure adopted in accordance

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with the Directive is inappropriate in a particular case for technical reasons or because it is insufficiently conclusive for the examination of an important health question, that Member State may temporarily suspend the measure in question in its territory but only for that particular case. It shall immediately inform the other Member States and the Commission thereof and give reasons for its decision.

According to the Directive 89/397/EEC (entry into force 20/6/1991), 'official control of foodstuffs' means an inspection by the competent authorities of the compliance: (a) of foodstuffs, (b) of food additives, vitamins, mineral salts, trace elements and other additives intended to be sold as such and (c) of materials and articles intended to come into contact with foodstuffs, with provisions aimed at preventing risks to public health, guaranteeing fair commercial transactions or protecting consumer interests, including provisions on consumer information. Control shall comprise one or more of the following operations in accordance with the conditions laid down in Articles 6–9 and in the light of the examination to be carried out: (1) inspection, (2) sampling and analysis, (3) inspection of staff hygiene, (4) examination of written and documentary material and (5) examination of any verification systems set up by the undertaking and of the results obtained. The following shall be subject to inspection: (a) the state and use which is made at the different stages, premises, offices, plant surroundings, means of transport, machinery and equipment, (b) raw materials, ingredients, technological aids and other products used for the preparation and production of foodstuffs, (c) semi-finished products, (d) finished products, (e) materials and articles intended to come into contact with foodstuffs, (f) cleaning and maintenance products and processes and pesticides, (g) processes used for the manufacture or processing of foodstuffs, (h) labelling and presentation of foodstuffs and (i) preserving methods.

In Directive 93/43/EEC (entry into force 14/12/1995), known as the HACCP (Hazard Analysis and Critical Control Point) requirements Directive, 'food hygiene' means all measures necessary to ensure the safety and wholesomeness of foodstuffs. The measures shall cover all stages after primary production, during preparation, processing, manufacturing, packaging, storing, transportation, distribution, handling and offering for sale or supply to the consumer. This Directive sets out the hygiene requirements for: (1) food premises, including outside areas and sites, (2) transport conditions, (3) equipment, (4) food waste, (5) water supply, (6) personal hygiene of persons in contact with food, (7) food, (8) wrapping and packaging, (9) heat treatment, which may be used to process certain foodstuffs and (10) training of food workers.

In Directive 93/99/EEC (entry into force 1/5/1995), the laboratory assessment becomes very clear since Member States shall (a) apply the criteria laid down in European Standard EN 45002 and (b) require the use of proficiency testing schemes as far as appropriate. The Commission shall appoint and designate specific officials to cooperate with the competent authorities of the Member States to monitor and evaluate the equivalence and effectiveness of official food control systems operated by the competent authorities of the Member States. The Commission shall send regular reports to the Member States concerned on the work of its specific officials. In criminal proceedings, the information can be used only with the prior consent of the sending Member State in accordance with, for those Member States who are parties to them, the international conventions and agreements in force on mutual assistance in criminal affairs. Where a Member State has rules permitting free access by persons to information held by competent authorities, this fact must be revealed at the time of the request to another Member State or during the exchange of information if no such request occurs. If it is not possible for the receiving Member State to restrict the giving out of the information in this way, it shall not be contrary to the terms of this Directive for the sending Member State to withhold the information.

Following the Directive 2002/99/EC (entry into force 1/1/2005; came into force 1/1/2005), products of animal origin shall be obtained from animals which (a) do not come from a holding, establishment, territory or part of a territory subject to animal health restrictions applicable to the animals and products concerned, under the rules, (b) in the case of meat and meat products, were not slaughtered in an establishment in which animals infected or suspected of being infected with one of the diseases or carcasses or parts thereof of such animals, were present during the slaughtering or production process, unless such suspicion has been ruled out, (c) in the case of aquaculture animals and products. Laying down lists of the third countries or regions of third countries from which imports of specified products of animal origin are permitted. A third country shall appear on such lists only if a Community audit of that country has taken place and demonstrates that the competent veterinary authority provides appropriate guarantees as regards compliance with Community legislation. Lists of the third countries or regions of third countries from which imports of specified products of animal origin are permitted. A third country shall appear on such lists only if a Community audit of that country has taken place and demonstrates that

the competent veterinary authority provides appropriate guarantees as regards compliance with Community legislation. When drawing up or updating those lists, particular account shall be taken of (a) the legislation of the third country, (b) the organisation of the competent veterinary authority and its inspection services in the third country, the powers of these services, the supervision to which they are subject, and the means at their disposal, including staff capacity, to apply their legislation effectively, (c) the actual animal health requirements applying to the production, manufacture, handling, storage and dispatch of products of animal origin intended for the Community, (d) the assurances which the competent veterinary authority of the third country can give regarding compliance or equivalence with the relevant animal health conditions, (e) any experience of marketing the product from the third country and the results of any import controls carried out, (f) the results of Community inspections and/or audits carried out in the third country, in particular the results of the assessment of the competent authorities or, where the Commission so requests, the report submitted by the competent authorities of the third country on the inspections which they have carried out, (g) the health status of livestock, other domestic animals and wildlife in the third country, with particular regard to exotic animal diseases and any aspects of the general health situation in the country which might pose a risk to public or animal health in the Community, (h) the regularity, speed and accuracy with which the third country supplies information on the existence of infectious or contagious animal diseases in its territory, particularly the notifiable diseases listed by the World Organisation for Animal Health (OIE) or, in the case of diseases of aquaculture animals, the notifiable diseases listed in the Aquatic Animal Health Code of the OIE and (i) the rules on the prevention and control of infectious or contagious animal diseases in force in the third country and their implementation, including rules on imports from other countries.

Directive 2004/41/EC (entry into force 20/5/2004), repealed certain Directives concerning food hygiene and health conditions for the production and placing on the market of certain products of animal origin intended for human consumption. The Directives which are repealed are (i) 64/433/EEC (health conditions of the production and marketing of fresh meat), (ii) 71/118/EEC (health problems affecting the production and placing on the market of fresh poultry meat), (iii) 72/461/EEC (health problems affecting intra-Community trade in fresh meat), (iv) 77/96/EEC (examination for *Trichinella spiralis* upon importation from third countries of fresh meat derived from domestic swine), (v) 77/99/EEC (health problems affecting the production and marketing of meat products and certain other products of animal origin), (vi) 80/215/EEC (animal health problems affecting intra-Community trade in meat products), (vii) 89/362/EEC (general conditions of hygiene in milk production holdings), (viii) 89/437/EEC (hygiene and health problems affecting the production and the placing on the market of egg products), (ix) 91/492/EEC (laying down the health conditions for the production and the placing on the market of live bivalve molluscs), (x) 91/493/EEC (laying down the health conditions for the production and the placing on the market of fishery products), (xi) 91/494/EEC (animal health conditions governing intra-Community trade in and imports from third countries of fresh poultry meat), (xii) 91/495/EEC (concerning public health and animal health problems affecting the production and placing on the market of rabbit meat and farmed game meat), (xiii) 92/45/EEC (public health and animal health problems relating to the killing of wild game meat), (xiv) 92/46/EEC (laying down the health rules for the production and placing on the market of raw milk, heat-treated milk and milk-based products), (xv) 92/48/EEC (laying down the minimum hygiene rules applicable to fishery products caught on board certain vessels) and (xvi) 94/65/EEC (laying down the requirements for the production and placing on the market of minced meat and meat preparations).

A summary of the Directives focused on controls and food hygiene rules is given in Table 2.1.

2.2.2 Imports from third countries and intra-Community trade; general provisions

The Directive 89/662/EEC (entry into force 22/12/1989) claims that for the purposes of this Directive veterinary check means any physical check and/or administrative formality which applies to the products and which is intended for the protection, direct or otherwise, of public or animal health. Products not subject to Community harmonisation are (1) rabbit and game meat, (2) raw milk and milk products, (3) aquaculture products intended for human consumption, (4) fishery products intended for human consumption, (5) live bivalve molluscs intended for human consumption, (6) game and rabbit meat products, (7) blood, (8) offal of animal fats, greaves and by-products of rendering, (9) honey, (10) snails intended for human consumption and (11) frogs' legs intended for human consumption. Member States shall ensure that during the checks carried out at the places where products from a third country may be brought into Community territory, such as ports, airports and frontier posts with third countries, the following measures are taken: (a) a documentary check is made on the product's origin, (b) where products are imported from third countries,

Table 2.1 Directives (titles, main points and comments) on controls and food hygiene rules.

Title	Main points	Comments
Directive 85/591/EEC (entry into force 23/12/1987) Introduction of Community methods of sampling and analysis for the monitoring of foodstuffs intended for human consumption	• Methods of sampling and analysis must be adopted by the Commission and the Council when necessary • Member States may use tested and scientifically valid methods provided that this does not hinder the free movement of products	
Directive 89/397/EEC (entry into force 20/6/1991) Official control of foodstuffs	• Member States must ensure that the competent authorities have, or have access to, a sufficient number of suitably qualified and experienced staff in such areas as (veterinary) medicine, chemistry, microbiology, food technology, food hygiene and law • The authorities responsible for the evaluation of the laboratories must meet the general criteria applicable to the official laboratory accreditation bodies set out in European Standard EN 45003 • This Directive shall not apply to metrological control	
Directive 93/43/EEC (entry into force 14/12/1995) Hygiene of foodstuffs	• This Directive lays down the general rules of hygiene for foodstuffs and the procedures for verification of compliance with these rules • The preparation, processing, manufacturing, packaging, storing, transportation, distribution, handling and offering for sale or supply of foodstuffs shall be carried out in a hygienic way • Enforcement of European Standard of the EN 29000 series	
Directive 93/99/EEC (entry into force 1/5/1995 and 1/11/1998 Article 3) Additional measures concerning the official control of foodstuffs	• Member States shall apply the criteria laid down in European Standard EN 45002 in the laboratories • Member States must ensure that the competent authorities have, or have access to, a sufficient number of suitably qualified and experienced staff	
Directive 2002/99/EC (entry into force 1/1/2005) Laying down the animal health rules governing the production, processing, distribution and introduction of products of animal origin for human consumption	• This Directive lays down the general animal health rules governing all stages of the production and the introduction from third countries of products of animals • Member States shall take measures to ensure that food business operators do not cause the spread of diseases transmissible to animals • Member States shall ensure that products of animal origin intended for human consumption are subjected to veterinary certification	
Directive 2004/41/EC (entry into force 20/5/2004) Repealing certain directives concerning food hygiene and health conditions for the production and placing on the market of certain products of animal origin intended for human consumption	• This Directive repeals 16 other Directives	Amendments – Directives • 89/662/EEC (entry into force 31/12/1992) 00 • 92/118/EEC (entry into force 30/6/1996) • 95/408/EEC (entry into force 31/12/1996) ▪ Replacements and repeals of Articles and Annex

Adapted from Arvanitoyannis *et al.* (2005).

they must be sent, under customs supervision, to inspection posts in order that veterinary checks may be carried out and (c) products of Community origin shall be subject to the rules.

According to Directive 90/425/EEC (entry into force 26/7/1990), diseases or epizootic diseases are foot-and-mouth disease (FMD), classical swine fever (CSF), African swine fever (ASF), swine vesicular disease (SVD), Newcastle disease (ND), rinderpest, peste des petits ruminants (PPR), vesicular stomatitis (VS), blue tongue, African horse sickness (AHS), viral equine encephalomyelitis (VEE), Teschen disease, avian influenza, sheep and goat pox, lumpy skin disease, rift valley fever and contagious bovine pleuropneumonia. This Directive applies to live animals (bovine and porcine animals, Equidae from third countries, bovine animals from third countries, sheep). However, it should be made clear that this Directive does not apply to live animals (goats, live poultry, domestic rabbits) and products (waste pathogens and hatching eggs). Member States shall ensure that only the animals and products fulfilling the following conditions may be the subject of trade: (a) the animals and products must fulfil the animal health requirements of the Member State of destination, (b) they must come from holdings, centres or organisations which are subject to regular official veterinary checks, (c) they must be identified in accordance with the requirements of Community rules and be registered in such a way that the original or transit holding, centre or organisation can be traced, (d) they must be accompanied by health certificates and/or any other documents for the animals and products, by the rules of the Member State of destination, (e) susceptible animals, or products of susceptible animals, must not originate from holdings, centres or organisations comply with the requirements of this Directive, (f) where the transport operation involves several places of destination, animals and products must be grouped together in as many consignments as there are places of destination and (g) where animals and products covered by the Directives referred to in Annex of this Directive which comply with Community rules are intended for export to a third country through the territory of another Member State, the transport operation must – except in cases of urgent need duly authorized by the competent authority in order to ensure the welfare of the animals – remain under customs supervision up to the point of exit from Community territory.

In Directive 91/174/EEC (entry into force 1/1/1992), the Member States should ensure that the following shall not be prohibited, restricted or impeded on zootechnical grounds: (i) intra-Community trade in pure-bred breeding animals of the bovine species, (ii) intra-Community trade in the semen and embryos of pure-bred breeding animals of the bovine species, (iii) the establishment of herd-books, provided that they comply with the requirements laid down to the Directive, (iv) the recognition of organisations or associations which maintain herd-books and (v) intra-Community trade in bulls used for artificial insemination. The following shall be determined in accordance with this Directive: (i) performance monitoring methods and methods for assessing cattle's genetic value, (ii) the criteria governing the recognition of breeders' organisations and associations, (iii) the criteria governing the establishment of herd-books, (iv) the criteria governing entry in herd-books and (v) the particulars to be shown on the pedigree certificate.

Furthermore, another Directive 91/496/EEC (entry into force 1/7/1992) claims that Member States shall ensure that (a) importers are obliged to give one working day's notice to the veterinary staff of the border inspection post where the animals are to be presented specifying the number, nature and estimated time of arrival of the animals, (b) the animals are conveyed directly under official supervision, where applicable, to a quarantine centre, (c) the animals may not leave such post or centre unless proof has been supplied in the form of the certificate and (d) the customs authority does not authorise release for free circulation in the territories unless proof has been supplied that the requirements have been fulfilled. Member States shall submit to the Commission the list of border inspection posts responsible for carrying out veterinary checks on animals and shall provide the following information: (a) nature of the border inspection post (port, airport, road checkpoint, rail checkpoint), (b) nature of the animals which could be checked at the border inspection post in question given the equipment and veterinary staff available, indicating any animals that cannot be checked at those border inspection posts and for registered Equidae the operating hours of a specially approved border inspection post, (c) staff assigned to veterinary checks, number of official veterinarians and number of specially qualified auxiliary staff or assistants, (d) description of the equipment and premises available for carrying out the documentary check, the physical check, sampling, the general tests and the specific tests ordered by the official veterinarian, (e) capacity of the premises available to house animals where necessary pending the test results, (f) nature of the equipment allowing a rapid exchange of information and (g) volume of trade.

The Directive 92/65/EEC (entry into force 29/7/1992) claims that diseases which are applied to this Directive are Newcastle disease, avian influenza, psittacosis, American foulbrood, foot-and-mouth disease, brucellosis (*Brucella* spp.), tuberculosis, classical swine fever and African swine fever. Member States shall take the necessary measures to (i) have the animals held examined regularly, (ii) notify the competent authority,

(iii) comply with the specific national measures to control a disease which is of particular importance to a given Member State, (iv) place on the market for the purposes of trade only animals which show no signs of disease and which come from holdings or areas not subject to any ban on animal health grounds and with respect to animals not accompanied by a health certificate or a commercial document and (v) comply with the requirements ensuring the welfare of the animals held. Semen collection centres must (1) be placed under the supervision of a centre veterinarian, (2) have different and physically separate premises for accommodating and isolating animals, collecting semen, cleaning and disinfecting equipment, processing semen, storing semen, (3) be built or kept separate in such a way as to prevent any contact with animals outside the centre and (4) have premises which are easily cleaned and disinfected.

In Directive 92/118/EEC (entry into force 4/4/1993), products, in which this Directive applies, are milk for human consumption, animal casings, hides and skins, pet food containing low-risk materials, bones and bone products, processed animal protein, blood and blood products of animal origin, serum from Equidae, rabbit meat and farmed game meat and apiculture products. Member States shall ensure that (1) trade in and imports of products of animal origin together with gelatins not intended for human consumption are not prohibited or restricted for animal health or public health reasons other than those arising from the application of this Directive or from Community legislation and in particular any safeguard measures taken, (2) any new product of animal origin intended for human consumption, which placing on the market of a Member State, must be checked the risk of spread of serious transmissible diseases which could result from movement of the product and (3) the other products of animal origin may not be the subject of trade or importation from third countries unless they meet the requirements of this Directive. Under the procedure provided: (a) specific requirements shall be established – in particular for the protection of the Community from certain exotic diseases or diseases transmissible to man – or guarantees equivalent to those conditions, (b) a Community list shall be drawn up of third country establishments which satisfy the requirements of this Directive and (c) the nature of any treatment or the measures to be taken to avoid recontamination of animal casings, eggs and egg products shall be established. The decisions provided for in the Directive must be taken on the basis of evaluation and, if appropriate, the opinion of the Scientific Veterinary Committee, of the real risk of the spread of serious transmissible diseases or of diseases transmissible to man which could result from movement of the product, not only for the species from which the product originates but also for other species which could carry the disease or become a focus of disease or a risk to public health. Experts from the Commission and the Member States shall carry out on-the-spot inspections to verify whether the guarantees given by the third country regarding the conditions of production and placing on the market can be considered equivalent to those applied in the Community. The experts from the Member States responsible for these inspections shall be appointed by the Commission, acting on proposals from the Member States. These inspections shall be made on behalf of the Community, which shall bear the cost of any expenditure involved.

The Directive 96/23/EEC (entry into force 23/5/1996) is primarily focused on residues of therapeutic substances. For the purposes of this Directive, 'residue' shall mean a residue of substances having a pharmacological action, of their metabolites and of other substances transmitted to animal products and likely to be harmful to human health; 'official sample' shall mean a sample taken by the competent authority which bears a reference to the species, the type, the quantity concerned, the method of collection and particulars identifying the sex of the animal and the origin of the animal or of the animal product. Monitoring plan for the detection of residues or substances shall (a) provide for detection of groups of residues or substances according to type of animal, (b) specify in particular the measures for detection of the presence of residues of the aforementioned substances in live animals, their excrement and body fluids and in animal tissues and products such as meat, milk, eggs and honey and (c) comply with the sampling rules and levels laid down in the Directive. The laboratories shall be responsible for (a) coordinating the work of the other national laboratories responsible for residue analysis, in particular by coordinating the standards and methods of analysis for each residue or residue group concerned, (b) assisting the competent authority in organising the plan for monitoring residues, (c) periodically organising comparative tests for each residue or residue group assigned to them, (d) ensuring that national laboratories observe the limits laid down, (e) disseminating information supplied by Community reference laboratories and (f) ensuring that their staff are able to take part in further training courses organised by the Commission or by Commission reference laboratories.

According to Directive 97/78/EEC (entry into force 19/2/1998), the official veterinarian shall carry out the following checks: (a) an identity check on each consignment to ascertain that the products correspond to the information given in the accompanying certificates or documents: [(i) where products of animal origin arrive in containers, verification that the seals fixed by

the official veterinarian, are intact and that the information appearing thereon corresponds to that given in the accompanying document or certificate and (ii) in other cases, for all types of product, a check that the stamps, official marks and health marks identifying the country and establishment of origin are present and conform to those on the certificate or document and in addition, for wrapped or packaged products, a check on the specific labelling provided for in veterinary legislation], (b) a physical check on each consignment [(i) in order to ascertain that the products satisfy the requirements of Community legislation and are in a fit state to be used for the purpose specified in the accompanying certificate or document]. Border inspection posts must (a) be located in the immediate vicinity of the point of entry into an area which is designated by the customs authorities and (b) be placed under the authority of an official veterinarian, who shall be effectively responsible for the checks. The official veterinarian may be assisted by specially trained auxiliary staff. Products which are to be monitored pursuant to Community legislation from the border inspection post of arrival to the establishment at the place of destination shall be forwarded under the following conditions: (i) the consignments in question shall be dispatched from the border inspection post of arrival to the establishment at the place of destination under the supervision of the competent authority in leakproof vehicles or containers sealed by the competent authorities, (ii) the official veterinarian at the border inspection post concerned shall inform the veterinary authority in charge of the establishment at the place of destination of the consignment of the place of origin and the place of destination of the product via the ANIMO network, (iii) the products shall undergo, in the establishment at the place of destination, the treatment defined in the relevant Community legislation and (iv) the official veterinarian responsible for an intermediate warehouse, shall be informed by the management of the establishment of destination or of the intermediate warehouse of the arrival of the product at its destination, and shall within 15 days notify the official veterinarian at the border inspection post who notified him (supervisor) of the shipment.

Some representative points and comments (repeals, amendments) of the Directives with regard to imports from third countries and intra-Community trade and general provisions are given in Table 2.2.

2.2.3 Production and placing on the market – milk

In Directive 89/384/EEC (entry into force 1/7/1990), the Member States should ensure that the checks on the freezing point of untreated milk are carried out according to the following detailed procedures: (1) the untreated milk of each holding must be checked regularly by random sampling and (2) if the results of the check refute the suspicion of water being added, the untreated milk may be used for producing heat-treated milk. Where the milk of a single holding is delivered directly to a treatment establishment, these samples are to be taken when the milk is collected from the holding with precautions, however, being taken to prevent any fraud during transport either before unloading at the treatment establishment or when the milk is delivered there directly by the farmer. If the results of a check lead the competent authority to suspect that water is being added, it shall take an authentic sample on the holding. An authentic sample is a sample representing the milk of one completely supervised morning or evening milking beginning not less than 11 hours or more than 13 hours after the previous milking. Where milk is delivered from several holdings, samples may only be taken when the untreated milk enters the treatment establishment or collection or standardisation centre with spot checks, however, being carried out on the holdings.

Following the Directive 92/46/EEC (entry into force 1/1/1994), milk and milk-based products must not come from a surveillance zone established under this Directive, unless the milk has undergone, under the supervision of the competent authority, initial pasteurisation (71.7°C for 15 seconds) followed by (a) a second heat treatment resulting in a negative reaction to the peroxidase test or (b) a drying procedure including heating having an effect equivalent to the heat treatment or (c) a second treatment whereby pH is reduced and kept for at least 1 hour at pH less than 6. If the milk is not collected within 2 hours of milking, it must be cooled to a temperature of 8°C or lower in the case of daily collection or 6°C if collection is not daily. While the milk is being transported to the treatment and/or processing establishment, the temperature of the cooled milk must not exceed 10°C unless the milk has been collected within 2 hours of milking. In the case of treatment establishments, heat-treatment equipment approved or authorised by the competent authority, fitted with (i) an automatic temperature control, (ii) a recording thermometer, (iii) an automatic safety device preventing insufficient heating, (iv) an adequate safety system preventing the mixture of heat-treated milk with incompletely heated milk and (v) an automatic recording device for the safety system referred to in the preceding indent or a procedure for monitoring the system's effectiveness. However, when approving establishments, the competent authorities may authorise different equipment with

Table 2.2 Directives (main points and comments) related to imports from third countries and intra-Community trade; general provisions.

Title	Main points	Comments
Directive 89/662/EEC (entry into force 22/12/1989) Veterinary checks in intra-Community trade with a view to the completion of the internal market	• The Directive laid down detailed rules governing veterinary checks on animals entering the Community from third countries • Member States shall ensure that the products intended for trade have been obtained, checked, marked and labelled in accordance with Community rules • A documentary check by the competent authorities must be carried out for each consignment of animals from third countries • If a serious animal health reason warrants, the Commission may prohibit or apply special conditions to imports of animals originating directly or indirectly in the third country concerned	Amendments • Directive 91/496/EEC (entry into force 24/9/1991) • Directive 92/67/EEC (entry into force 14/9/1992) • Directive 92/118/EEC (entry into force 4/4/1993) ▪ Laying down the principles governing the organisation of veterinary checks on animals entering the Community from third countries
Directive 90/425/EEC (entry into force 26/7/1990) Veterinary and zootechnical checks applicable in intra-Community trade in certain live animals and products with a view to the completion of the internal market	• This Directive affected neither checks on the welfare of animals during transport nor checks carried out as part of tasks conducted in a non-discriminatory manner by authorities • Checks at origin • Checks on arrival at destination • If a serious animal health reason warrants, the Commission may prohibit or apply special conditions to imports of animals originating directly or indirectly in the third country concerned	Amendments – Directive • 90/539/EEC (entry into force 1/1/1992) • 90/675/EEC (entry into force 31/12/91) • 91/67/EEC (entry into force 1/1/1993) • 91/174/EEC (entry into force 1/1/1992) • 91/496/EEC (entry into force 1/1/1992) • 91/628/EEC (entry into force 1/1/1993) • 92/60/EEC (entry into force 1/7/1992) • 92/65/EEC (entry into force 1/1/1994) • 92/102/EEC (entry into force 1/1/1994 for porcine animals and 1/1/1995 for ovine and caprine animals) • 92/118/EEC (entry into force 1/1/1994) • 2002/33/EC (entry into force 19/11/2002) ▪ Replacement of Articles and Annexes
Directive 91/174/EEC (entry into force 1/1/1992) Laying down zootechnical and pedigree requirements for the marketing of pure-bred animals	• The Directive applies to the marketing of pure-bred animals and their semen, ova and embryos, other than those of bovine, porcine, ovine, caprine and equine species • Member States must ensure that intra-Community trade in pure-bred animals and their semen, ova or embryos may not be prohibited, restricted or impeded on zootechnical or pedigree grounds	
Directive 91/496/EEC (entry into force 1/7/1992) Laying down the principles governing the organisation of veterinary checks on animals entering the Community from third countries	• Veterinary checks in respect of animals from third countries entering the Community shall be carried out by the Member States • Organisation and effects of checks • Requirements for the transportation of animals from one third country to another • Veterinary experts from the Commission shall check that the inspection posts and quarantine centres satisfy the conditions for approval	Repeal • Directive 72/462/EEC Amendment • Directive 96/43/EC (entry into force 1/7/1996) ▪ Addition in the Annex of this Directive

(*Continues*)

Table 2.2 (*Continued*)

Title	Main points	Comments
Directive 92/65/EEC (entry into force 29/7/1992) Laying down animal health requirements governing trade in and imports into the Community of animals, semen, ova and embryos not subject to animal health requirements laid down in specific Community rules	• The Directive laid down the animal health requirements for the placing on the market in the European Union (EU) of animals and products of animal origin • Laying down the animal health requirements applicable to trade in ruminants, bees, lagomorphs, foxes, cats and dogs • Laying down the animal health requirements applicable to trade in semen, ova and embryos of certain animals like Equidae, sheep and goats	Amendments • Regulation (EC) No. 998/2003 (entry into force 3/7/2003) • Directive 2004/68/EC (entry into force 20/5/2004) ▪ Changes in the lists of Annexes of compulsorily notifiable diseases
Directive 92/118/EEC (entry into force 4/4/1993) Laying down animal health and public health requirements governing trade in and imports into the Community of products not subject to the said requirements laid down in specific Community rules	• The Directive covers certain products of animal origin, in particular animal casings intended for human consumption and processed animal proteins intended for human consumption. Trade in or imports of any new product of animal origin must be authorised by the Council, following assessment by the Commission and an opinion from the European Food Safety Authority • Specific conditions may be imposed, especially in order to protect the EU from certain exotic diseases and diseases transmissible to humans	Amendments – Directive • 94/466/EC (entry into force 1/12/94) • 94/723/EC (entry into force 1/12/1994) • 95/1/EC (entry into force 21/1/1995) • 95/338/EC (entry into force 30/9/1995) • 95/339/EC (entry into force 30/9/1995) • 96/103/EC (entry into force 20/9/1996) • 96/340/EC (entry into force 1/7/1997) • 96/90/EC (entry into force 16/1/1997) • 96/405/EC (entry into force 19/6/1997) • 1999/724/EC (entry into force 1/6/2000) • 2000/7/EC (entry into force 1/1/2001) • 2003/721/EC (entry into force 1/1/2004) ▪ Additions and replacements of Articles and Annexes
Directive 96/23/EEC (entry into force 23/5/1996) Measures to monitor certain substances and residues thereof in live animals and animal products	• The substances to be monitored are divided into two groups: substances having anabolic effect and unauthorised substances on the one hand and veterinary drugs and contaminants on the other • Definitions (official sample, approved laboratory and residue) • Monitoring plans for the detection of residues or substances • Official control measures	Repeals • Directive 85/358/EEC • Directive 86/469/EEC • Directive 89/187/EEC • Directive 91/664/EEC ▪ These are repealed from 1/7/1997
Directive 97/78/EEC (entry into force 19/2/1998) Laying down the principles governing the organisation of veterinary checks on products entering the Community from third countries	• This proposal applies to products from third countries • Definitions (products, documentary check, import etc.) • A documentary check by the veterinary staff of the border inspection post or by the competent authorities must be carried out on each consignment of products from third countries • The Directive defines the conditions governing the transportation of products from one third country to another	Amendment • Directive 1999/67/EC (entry into force 18/11/1999) ▪ Correction in the definitions and changes in the Articles

Adapted from Arvanitoyannis *et al.* (2005).

equivalent performance guarantees and equal assurances with regard to hygiene. The operator or manager of the processing establishment must take all necessary steps to ensure that the raw milk is heat treated or used, in the case of products made with raw milk: (i) as soon as possible after acceptance if the milk has not been refrigerated, (ii) within 36 hours of acceptance if the milk is kept at a temperature not exceeding 6°C, (iii) within 48 hours of acceptance if the milk is kept at a temperature not exceeding 4°C and (iv) within 72 hours for buffalo's, sheep's and goat's milk. However, for technological reasons concerning the manufacture of certain milk-based products, the competent authorities may authorise the times and temperatures referred to in the above indents to be exceeded.

All the Directives dealing with production and placing on the market – milk – are given in Table 2.3.

2.2.4 Production and placing on the market – meat

In Directive 91/495/EEC (entry into force 1/1/1993), the Member States may authorise (a) the direct supply of rabbit meat by a small producer to a private individual for his or her own consumption and (b) the supply of fresh rabbit meat in small quantities, by farmers who produce rabbits on a small scale either directly to the final consumer at those local markets which are closest to their farms or to a retailer with a view to direct sale to the final consumer, provided that such retailer conducts his or her business in the same locality as that of the producer or in a neighbouring locality. The said possible derogation shall not include itinerant sales, mail order sales and, as far as the retailer is concerned, sales on a market. The official service may authorise the slaughter of farmed game in the place of origin, where it cannot be transported, in order to avoid any risk for the handler or to protect the welfare of the animals. This authorisation may be granted provided that (i) the herd undergoes regular veterinary inspection and is not under any restrictions, (ii) a request is submitted by the owner of the animals, (iii) the official service is informed in advance of the date of slaughtering of the animals, (iv) the holding has a centre for mustering wild animals where an ante-mortem inspection of the group for slaughter can be carried out, (v) the holding has premises suitable for the slaughter, sticking and bleeding of the animals, (vi) slaughter by means of sticking and bleeding is preceded by stunning, which must be carried out in the conditions laid down in this Directive, (vii) the slaughtered and bled animals are hung as quickly as possible after slaughter and are transported under satisfactory hygiene conditions to a slaughterhouse, in a container or means of transport in which the ambient temperature is maintained at between 0 and 4°C. Evisceration must be carried out no later than 3 hours after stunning and (viii) during transportation to the

Table 2.3 Directives (main points and comments) related to production and placing on the market – milk.

Title	Main points	Comments
Directive 89/384/EEC (entry into force 1/7/1990) Establishing the detailed procedures for carrying out checks to ensure that the freezing point of untreated milk	• Laying down the health and animal health requirements for heat-treated milk intended for intra-Community trade • Technical descriptions of the various milk treatments • Milk treatment establishments and collecting and standardisation centres must be approved by Member States • Inspections of milk production holdings to ensure hygiene requirements are fulfilled	Amendment • Directive 92/608/EEC (entry into force 20/1/1993)
Directive 92/46/EEC (entry into force 1/1/1994) Laying down the health rules for the production and placing on the market of raw milk, heat-treated milk and milk-based products	• General conditions of hygiene in treatment establishments and processing establishments • Production holdings (i.e. farms, where milk is produced) shall undergo regular checks to ensure that hygiene requirements are being fulfilled • Measures for use by Member States in the case of the outbreak of disease • Veterinary experts are authorised to undertake spot checks where this is required for uniform application of the Directive	Amendments • Directive 92/47/EEC (entry into force 1/1/1994) • Directive 94/71/EEC (entry into force 31/12/1994) ▪ Addition and corrections in the Articles and Annexes Repeal • Directive 85/397/EEC from 1/1/1994

Adapted from Arvanitoyannis *et al.* (2005).

slaughterhouse the slaughtered animals are accompanied by a certificate issued by the veterinary service attesting to the favourable outcome of the antemortem inspection, the correct conduct of bleeding and the time of slaughter. Rabbits shall be declared totally unfit for human consumption where the post-mortem inspection reveals the following: (i) diseases transmissible to man or animals, (ii) malignant or multiple tumours, multiple abscesses, (iii) extensive parasitic infestation in the subcutaneous or muscle tissues, (iv) presence of residues of forbidden substances or residues in excess of permitted Community levels, including substances with a pharmacological effect, (v) poisoning, (vi) extensive injuries or extensive blood or serum imbibition, (vii) anomalies as regards colour, smell or taste and (viii) anomalies as regards consistency, particularly oedema or severe emaciation.

The Directive 92/45/EEC (entry into force 4/10/1992) specifies that Member States shall ensure that wild game meat comes from wild game which (i) has been killed in a hunting area by means authorised under national legislation governing hunting and (ii) immediately after killing has been prepared and transported within a maximum of 12 hours to a processing house. The official veterinarian must ensure that wild game meat is excluded from human consumption: (i) if it is found to contain defects or if it has been seized in accordance with this Directive, (ii) if the checks have revealed the presence of a disease communicable to man, (iii) if it comes from animals which have ingested substances which are likely to make the meat dangerous or harmful to human health and on which a decision has been taken and (iv) if, without prejudice to any Community legislation applicable to ionisation, it has been treated with ionising or ultraviolet radiation or by means of substances likely to affect its organoleptic properties or using colourings other than those used for health marking. Wild game must undergo the following operations immediately after killing: (i) large wild game must be drawn and eviscerated, (ii) the thoracic viscera, even if detached from the carcase, and the liver and the spleen, must accompany the game and be identified in such a way that the official veterinarian can carry out the post-mortem inspection of the viscera in conjunction with the rest of the carcase, the other abdominal viscera must be removed and inspected on the spot. The head may be removed as a trophy and (iii) small wild game may be totally or partially eviscerated on the spot or in a processing house where the game is transported to the said house at an ambient temperature not exceeding 4°C within 12 hours of being killed. Wild game must be chilled immediately after the operations so that the internal temperature is +7°C or lower in the case of large game or +4°C or lower in the case of small game. If the external temperature is not sufficiently low, killed game must be moved as soon as possible, and in any event not more than 12 hours after being killed, to a wild game processing house or to a collection centre. Evisceration must be carried out without undue delay upon arrival at the wild game processing house, if it has not been carried out on the spot. The lungs, heart, liver, kidney, spleen and mediastinum may either be detached or left attached to the carcase by their natural connections. Supervision by the official veterinarian must include the following tasks: (i) supervision of the entry and exit of meat, (ii) health inspection of meat held in processing houses, (iii) health inspection of meat prior to cutting and when it leaves the processing houses referred to in the second indent, (iv) supervision of the cleanliness of the premises, facilities and instruments and of staff hygiene, including their clothing and (v) any other supervision which the official veterinarian considers necessary for ensuring compliance with this Directive.

According to Directive 94/65/EEC (entry into force 1/1/1996), minced meat must meet the following requirements: (a) the fresh meat from which it is obtained must: (i) where it has been frozen or deep-frozen, be obtained from fresh boned meat which has been stored for no longer than 18 months for beef and veal, 12 months for sheep meat and 6 months for pig meat, after freezing or deep-freezing, in a cold store. However, the competent authority may authorise the boning of pig meat and sheep meat on the spot immediately before mincing where this operation is carried out in satisfactory conditions of hygiene and quality, (ii) where it has been chilled, be used within no more than 6 days after slaughter of the animals or within no more than 15 days after slaughter of the animals in the case of boned, vacuum-packed beef and veal; (b) the minced meat must have undergone cold treatment within a period of not more than 1 hour after portioning and wrapping, except where processes requiring the lowering of the internal temperature of the meat during production are used; (c) the minced meat must be packaged and presented in one of the following forms: (i) chilled, in this case obtained from meat and cooled to an internal temperature below +2°C in the shortest time possible and (ii) deep-frozen, and in this case obtained from meat and cooled to an internal temperature below −18°C as quickly as possible; (d) the minced meat must not have been subjected to ionising radiation or ultraviolet treatment and (e) possibly combined with the name of the species of animal from which the meat was obtained, may be used on packages only if the requirements are met for those designations.

Table 2.4 Directives (titles, main points and comments) for production and placing on the market – meat.

Title	Main points	Comments
Directive 91/495/EEC (entry into force 1/1/1993) Public health and animal health problems affecting the production and placing on the market of rabbit meat and farmed game meat	• Laying down requirements concerning public health and animal health problems affecting the production and placing on the market of rabbit meat and farmed game meat • Definitions (rabbit meat, farmed game meat etc.) • Rules applicable to the production and placing on the market of rabbit meat • Rules applicable to the production and marketing of farmed game meat • Slaughtering, cutting and processing establishments must be approved by the Member States	Amendment • Directive 94/65/EEC (entry into force 1/1/1996) ▪ Addition in the Annex
Directive 92/45/EEC (entry into force 4/10/1992) Public health and animal health problems relating to the killing of wild game and the placing on the market of wild game meat	• Laying down public health and animal health rules applicable to the killing of wild game and to the preparation and placing on the market of wild game meat • This Directive shall not apply to small numbers of wild game • Definitions (wild game, large wild game, wild game meat, collection centre etc.) • Provisions applicable to Community production and trade of wild game meat	Amendment • Directive 92/116/EEC (entry into force 4/4/1993) ▪ Replacement and correction of the Articles and Annexes
Directive 94/65/EEC (entry into force 1/1/1996) Laying down the requirements for the production and placing on the market of minced meat and meat preparations	• Laying down rules for the production, placing on the market in the Union and importing of meat preparations and minced meat • This Directive shall not apply to meat preparations and minced meat which are produced in retail shops • This Directive shall not apply to mechanically recovered meat for industrial use • Placing on the market of minced meat • Placing on the market of meat preparations	Repeal • Directive 88/657/EEC from 1/1/1996

Adapted from Arvanitoyannis *et al*. (2005).

Production plants must have at least (a) a room for mincing and wrapping separate from the cutting room and equipped with a recording thermometer or recording telethermometer, (b) a room for packaging, (c) a room or cabinets for storing salt and (d) refrigeration equipment enabling the temperatures. Conditions for the production of minced meat: (1) meat must be examined before mincing or cutting up, in accordance with Article 7. All soiled and suspect parts shall be removed and condemned before the meat is minced, (2) minced meat may not be obtained from scrap cuttings, scrap trimmings or from mechanically recovered meat, (3) minced meat may be deep-frozen only once and (4) immediately after production, the minced meat must be hygienically wrapped and, after packaging, be cooled to and stored at certain temperatures.

The titles, main points and comments of the Directives about production and placing on the market – meat – are summarised in Table 2.4.

2.2.5 Specific provisions – bovine and porcine animal

The Directive 64/432/EEC (entry into force 30/6/1964) makes clear that for the purposes of this Directive, 'animal for slaughter' means a bovine animal or swine intended to be taken on arrival in the country of destination direct to a slaughterhouse or to a market adjoining a slaughterhouse under whose rules all animals may be removed, in particular after the market, only to a slaughterhouse approved for this purpose by the competent central authority. In the latter case, the animals must be slaughtered at that slaughterhouse not later than 72 hours after arriving at the market and 'animals for breeding or production' mean bovine animals and swine, including those intended for breeding, milk or meat production or draft purposes. Bovine animals and swine covered by this Directive must (a) show no clinical sign of disease on the day of loading; (b) have

been obtained from a holding which officially fulfils the following conditions: (i) it shall be situated in the centre of an epizootic-free area, (ii) it shall, for at least 3 months prior to consignment, have been free from foot-and-mouth disease and bovine brucellosis in the case of bovine animals and from foot-and-mouth disease, bovine and porcine brucellosis, swine fever and contagious porcine paralysis (Teschen disease) in the case of swine and (iii) it shall, for at least 30 days prior to consignment, have been free from all other compulsorily notifiable diseases which are contagious or infectious for the animal species in question; (c) in the case of animals for breeding and production, the official veterinarian may certify that the animals have remained on the holding during the 30 days preceding loading and placed under official veterinary supervision, it being thus possible to certify that they belong to the holding; (d) be identified by an official or officially approved earmark or, in the case of swine, by a permanent identification stamp; (e) be sent direct from the holding to the actual place of loading: (i) without coming into contact with cloven-hoofed animals other than bovine animals and swine which fulfil the conditions laid down for intra-Community trade, (ii) segregated into animals for breeding or production and animals for slaughter and (iii) in transport vehicles or containers which have first been cleansed and disinfected with a disinfectant officially authorised in the exporting country; (f) be loaded for transportation to the country of destination at a specific place at the centre of an epizootic-free area; (g) after loading be sent direct and as quickly as possible to the frontier post of the exporting country and (h) be accompanied during transportation to the country of destination by a health certificate which shall be drawn up on the day of loading, in the language of the country of destination at least, and be valid for 10 days. Bovine animals for slaughter, if over 4 months old, must in addition (a) have been vaccinated not less than 15 days and not more than 4 months before loading against types A, O and C of the foot-and-mouth disease virus, using an inactivated virus vaccine approved and controlled by the competent authority of the exporting country, however, the period of validity of the vaccination shall be extended to 12 months in the case of bovine animals revaccinated in Member States where such animals are vaccinated annually and where they are systematically slaughtered when they contract foot-and-mouth disease, (b) if they do not come from an officially tuberculosis-free bovine herd, have reacted negatively to an intradermal tuberculin test and (c) if they do not come from an officially brucellosis-free bovine herd nor from a brucellosis-free bovine herd have shown a brucella count lower than 30 IU of agglutination per millilitre when given a sero-agglutination test complying with the provisions of the Directive.

According to Directive 72/462/EEC (entry into force 1/1/1976), applicable to importations from third countries of (i) domestic bovine animals and swine for breeding, production or slaughter and (ii) fresh meat of domestic animals of the following species: bovine animals, swine, sheep and goats and solipeds. However, it shall not apply to (a) animals intended exclusively for grazing or draft purposes, on a temporary basis, in the vicinity of the Community frontiers, (b) meat forming part of travellers' personal luggage and intended for their personal consumption, in so far as the amount or quantity transported does not exceed 1 kg per person and provided that the meat comes from a third country or part of a third country, (c) meat sent as small packages to private persons provided that such meat is not imported by way of trade, in so far as the quantity sent does not exceed 1 kg and provided that the meat comes from a third country or part of a third country and (d) meat for consumption by the crew and passengers on means of transport using international routes. The Member States shall only authorise the importation of the animals referred to in this Directive if they come from non-Member States: (a) free from any disease to which the animals are susceptible [(i) for 12 months, in respect of cattle plague exotic foot-and-mouth disease, contagious pleuropneumonia, African swine fever and contagious porcine paralysis (Teschen disease), or (ii) for 6 months, in respect of blue tongue disease and contagious vesiculate stomatitis] and (b) which have not been vaccinated during the preceding 12 months against the diseases to which animals are susceptible. The Member States shall authorise the importation of bovine animals and swine only on production of a certificate drawn up by an official veterinarian of the exporting non-Member State. This certificate must (a) be issued on the day of loading of the animals for consignment to the country of destination, (b) be worded at least in one of the official languages of the country of destination and in one of the official languages of the country carrying out the import inspection, (c) the original of this certificate must accompany the animals, (d) provide proof that the bovine animals and swine meet the conditions laid down in this Directive and those laid down in pursuance thereof with regard to imports from third countries, (e) consist of one single sheet of paper and (f) be made out in the name of one single addressee.

Following the Directive 77/96/EEC (entry into force 1/1/1979), fresh meat originating in third countries which contains skeletal muscles shall be examined under the supervision and responsibility of an official veterinarian in order to be admitted to intra-Community

trade. The examination shall take place in a slaughterhouse approved in the exporting country. The examination shall take place before the health marking. If it is not possible to carry out the examination in the exporting country, the Member State for which the fresh meat is intended may authorise its importation provided that the examination is carried out within its territory at the time of the public health inspection.

> The authorization for a slaughterhouse to carry out the examination and of a cutting plant to cut up or bone meat which has undergone such examination, or the authorization for an establishment to carry out the freezing treatment referred to this Directive. Account shall be taken of the guarantees given in respect of compliance with this Directive and, in the case of slaughterhouses, of:
> (a) the presence of the rooms and apparatus necessary for carrying out the examination;
> (b) the qualifications of the personnel responsible for carrying out the examination.

The Member States shall draw up and communicate to the Commission the list of the inspection posts at which the examination and the freezing may be carried out. They shall ensure that these posts have the equipment necessary for carrying out the operations in question.

The Directive 77/504/EEC (entry into force 1/1/1979) specifies that the Member States shall ensure that the following shall not be prohibited, restricted or impeded on zootechnical grounds: (i) intra-Community trade in pure-bred breeding animals of the bovine species, (ii) intra-Community trade in the semen and embryos of pure-bred breeding animals of the bovine species, (iii) the establishment of herd-books, provided that they comply with the requirements of the Directive, (iv) the recognition of organisations or associations which maintain herd-books and (v) intra-Community trade in bulls used for artificial insemination. The following shall be determined in accordance with the procedure laid down in this Directive: (i) performance monitoring methods and methods for assessing cattle's genetic value, (ii) the criteria governing the recognition of breeders' organisations and associations, (iii) the criteria governing the establishment of herd-books, (iv) the criteria governing entry in herd-books and (v) the particulars to be shown on the pedigree certificate. Until the entry into force of the provisions provided for in the first, second and third indents of the Directive: (a) the official checks referred to in the first indent of the Directive carried out in each Member State and the herd-books in existence at present shall be recognised by the other Member States, (b) the recognition of breeders' organisations and associations shall continue to be governed by the rules at present in force in each Member State and (c) the introduction of new herd-books shall continue to meet the conditions at present in force in each Member State. Until the implementation of Community rules on the subject, the conditions applicable to imports of pure-bred breeding animals of the bovine species from non-member countries must not be more favourable than those governing intra-Community trade.

In Directive 88/407/EEC (entry into force 1/1/1990), the Member States shall, until 31 December 1992, authorise the admission of semen from bulls giving a negative reaction to the serum neutralisation test or the ELISA test for infectious bovine rhinotracheitis/infectious pustular vulvovaginitis or showing a positive result after vaccination in accordance with this Directive. Member States may, until 31 December 1992, authorise the admission of semen of bulls giving a positive reaction to the serum neutralisation test or the ELISA test for infectious bovine rhinotracheitis/infectious pustular vulvovaginitis and not having been vaccinated in accordance with this Directive. In that case, each consignment must pass an examination by inoculation into a live animal and/or a virus isolation test. This requirement shall not apply in respect of the semen of animals which, prior to their first vaccination at the insemination centre, reacted negatively to the tests. Member States shall make the admission of semen conditional upon submission of an animal health certificate drawn up by an official veterinarian of the Member State of collection. This certificate must (a) be drawn up in at least one of the official languages of the Member State of collection and one of those of the Member State of destination, (b) accompany the consignment to its destination in its original form, (c) be drawn up on a single sheet of paper and (d) be made out to a single consignee. A semen collection centre may appear on the list provided for in this Directive only if: (a) it is situated in one of the countries on the list, (b) it fulfils the requirements, (c) it has been officially approved for exports to the Community by the veterinary services of the third country concerned, (d) it is under the supervision of a centre veterinarian of the third country concerned and (e) it is subject to regular inspection by an official veterinarian of the third country concerned at least twice a year. Consideration shall be given to (a) the health situation in the area surrounding the semen collection centre, with particular reference to the diseases appearing on list A of the International Office of Epizootic Diseases, (b) the state of health of the herd in the semen collection centre, including testing requirements, (c) the state of health of the donor animal and testing requirements and (d) testing requirements in relation to semen. Semen

collection centres must (a) be placed under the permanent supervision of a centre veterinarian, (b) have at least animal housing including isolation facilities such as semen collection facilities including a separate room for the cleaning and disinfection or sterilisation of equipment, a semen processing room which need not necessarily be on the same site and a semen storage room which need not necessarily be on the same site, (c) be so constructed or isolated that contact with livestock outside is prevented, (d) be so constructed that the animal housing and the semen collecting, processing and storage facilities can be readily cleaned and disinfected, (e) have isolation accommodation which shall have no direct communication with the normal animal accommodation and (f) be so designed that the animal accommodation is physically separated from the semen processing room and both are separated from the semen storage room.

According to the Directive 88/661/EEC (entry into force 1/1/1991), Member States may not prohibit, restrict or impede on zootechnical grounds: (i) intra-Community trade in pure-bred breeding pigs or in their semen, ova and embryos, (ii) the establishment of herd-books and (iii) the official approval of breeders' associations or breeding organisations, which establish or maintain herd-book. The following shall be determined in accordance with the rules: (i) methods for monitoring performance and assessing the genetic value of pure-bred breeding pigs, (ii) the criteria governing the establishment of herd-books, (iii) the criteria governing entry in herd-books, (iv) the criteria for approval and supervision of breeders' associations and/or breeding organisations which establish or maintain herd-books and (v) the certificate. The following shall be determined in accordance with the procedure laid down in this Directive: (a) methods for monitoring performance and assessing the genetic value of pure-bred breeding pigs, (b) the criteria governing the establishment of herd-books, (c) the criteria governing entry in herd-books, (d) the criteria for approval and supervision of breeders' associations and/or breeding organisations which establish or maintain herd-books and (e) the certificate. Member States may not prohibit, restrict or impede on zootechnical grounds: (a) intra-Community trade in hybrid breeding pigs or the semen, ova and embryos of such animals, (b) the establishment of registers, provided that they meet the conditions laid down pursuant to the Directive and (c) the official approval of breeders' associations and/or breeding organisations and/or private undertakings which establish or maintain registers.

The Directive 89/556/EEC (entry into force 1/1/1991) defines the animal health conditions governing intra-Community trade in and importation from third countries of fresh and frozen embryos of domestic animals of the bovine species. This Directive shall not apply to embryos resulting from in vitro fertilisation nor to embryos subjected to sexing, splitting (twinning), cloning or any manipulation which interferes with the integrity of the 'zona pellucida'. Each Member State shall ensure that embryos shall not be sent from its territory to that of another Member State unless they meet the following conditions: (a) they must have been conceived as a result of artificial insemination with semen from a donor sire standing at a semen collection centre, (b) they must have been collected from domestic animals of the bovine species whose health status complies with this Directive, (c) they must have been collected, processed and stored by an embryo collection team, (d) they must be accompanied, during transport to the Member State of destination, by an animal health certificate. Importation of embryos from the territory of a third country shall take place only if the embryos (a) come from donor animals which, immediately prior to the collection of their embryos, have remained for at least 6 months in the territory of the third country concerned, and in a maximum of two herds complying with at least the requirements and (b) comply with the animal health requirements imports of embryos from that country. Consideration shall be given to (a) the health situation in the area surrounding the place of embryo collection, with particular reference to the diseases appearing on list of the International Office of Epizootic Diseases, (b) the state of health of the herd concerned in the embryo collection, including testing requirements, (c) the state of health of the donor animal and testing requirements and (d) collecting, processing and storing requirements in relation to embryos. If a contagious animal disease which can be carried by embryos breaks out or spreads or if any other reason connected with animal health which might endanger the health of the livestock in a Member State so justify and where: (i) the territory of a Member State is concerned, the safeguard measures are laid down and (ii) all or part of the territory of a third country is concerned, the Member State of destination shall prohibit the importation of those embryos whether imported directly or indirectly through another Member State, either from the whole of the third country or from part only of its territory.

Directive 90/429/EEC (entry into force 31/12/1991) laid down the animal health conditions applicable to intra-Community trade in and imports from third countries of semen of domestic animals of the porcine species. Intra-Community trade in semen requires compliance with regulations concerning collection, processing, storage and transport as well as provisions on protection against the spread of Aujeszky's disease.

The Directive lays down that each Member State shall send the list of semen collection centres and their veterinary registration numbers to the other Member States and to the Commission. It also lays down that each consignment of semen must be accompanied by an animal health certificate drawn up by an official veterinarian of the Member State of collection. Imports of porcine semen may only be made from those third countries on the list of semen collection centres. Member States shall authorise the import of semen only on submission of an animal health certificate drawn up and signed by an official veterinarian of the third country of collection. The semen must fulfil the animal health requirements adopted for imports of semen from those countries.

According to Decision 1999/879/EC (entry into force 1/1/2000), Member States shall ensure that the placing on the market of bovine somatotropin on Community territory or within their jurisdiction for the purpose of its marketing and administration thereof to dairy cows by any means whatsoever shall be prohibited. Undertakings buying or producing bovine somatotropin substances and undertakings authorised in any capacity to market such substances shall be required to keep registers detailing, in chronological order, quantities produced or acquired and those sold or used for purposes other than placing on the market and the names of the persons to whom such quantities were sold or from whom they were purchased. The above information must be made available to the competent authority at its request and, in the case of computerised records, in the form of a printout. The prohibition shall not affect the production of bovine somatotropin in the Member States, or imports, for the purposes of its export to third countries.

All the Directives with regard to specific provisions – bovine and porcine animals – are given in Table 2.5.

2.2.6 Specific provisions – ovine and caprine animals

The Directive 72/462/EEC (entry into force 1/1/1976) applies to imports from third countries of domestic bovine animals and swine for breeding, production or slaughter and fresh meat of domestic animals of the following species: bovine animals, swine, sheep, goats and solipeds. This Directive shall not apply to (a) animals intended exclusively for grazing or draft purposes, on a temporary basis, in the vicinity of the Community frontiers, (b) meat forming part of travellers' personal luggage and intended for their personal consumption, in so far as the amount or quantity transported does not exceed 1 kg per person and (c) meat for consumption by the crew and passengers on means of transport using international routes. In deciding whether a slaughterhouse, a cutting plant or a cold store situated outside a slaughterhouse or plant may appear on one of the lists referred to this Directive particular account shall be taken of: (a) the guarantees which the third country can offer with regard to compliance with the provisions of this Directive, (b) the third country's regulations with regard to administering to animals for slaughter any substances which might affect the wholesomeness of the meat, (c) compliance in each particular case with the provisions of this Directive and (d) the organisation of the meat inspection services of the third country or part of the country, the powers of these services and the supervision to which they are subject. The Member States shall authorise the importation of bovine animals and swine if, before the day of loading for transportation to the country of destination, these animals have remained in the territory or part of the territory of a non-Member State: (a) for not less than 6 months in the case of animals for breeding or production and (b) for not less than 3 months in the case of animals for slaughter. This period shall date from birth in the case of animals which are less than 6 or 3 months old, respectively. The Member State which carried out the inspection shall take all those measures which it deems to be necessary. The Member States shall authorise imports of fresh meat in the form of carcases, possibly cut in half in respect of swine, and cut in halves or in quarters in respect of bovine animals and solipeds, only if it is possible to reconstruct the entire carcase of each animal. Such importation shall be subject to the following conditions: fresh meat must (a) have been obtained in a slaughterhouse, (b) come from an animal for slaughter which has undergone a post-mortem health inspection carried out by a veterinary official and been deemed suitable for slaughter in accordance with the provisions of this Directive, (c) have been treated according to the hygiene conditions, (d) have been inspected post-mortem by an official veterinarian and have shown no change except for traumatic lesions incurred shortly before slaughter or localised malformations or changes provided that it is established, if necessary by appropriate laboratory tests, that these do not render the carcase and offal unfit for human consumption or dangerous to human health, (e) be accompanied by a public health certificate, (f) have been stored after post-mortem inspection under satisfactory hygienic conditions in storage plants and (g) have been transported to the country of destination under satisfactory hygienic conditions.

In EU Directive 89/361/EEC (entry into force 11/1991), all zootechnical problems arising from intra-Community trade in pure-bred breeding sheep and goats and the semen, ova and embryos thereof are

Table 2.5 Directives (main points and comments) dealing with specific provisions – bovine and porcine animals.

Title	Main points	Comments
Directive 64/432/EEC (entry into force 30/6/1964) Animal health problems affecting intra-Community trade in bovine animals and swine	• The Directive applies to intra-Community trade in bovine animals or swine for breeding, production or slaughter • Definitions (animal for slaughter, animals for breeding or production, brucellosis-free bovine animal, epizootic-free area etc.) • Bovine and porcine animals, on the day of loading, must not display any clinical sign of disease and must be accompanied by a health certificate during transport to the country of destination • Animals for slaughter which have been taken on arrival in the country of destination must be slaughtered there as soon as possible	Amendments – Directive • 80/1098/EEC (entry into force 20/11/80) • 80/1274/EEC (entry into force 31/12/80) • 81/476/EEC (entry into force 1/7/1981) • 82/61/EEC (entry into force 10/2/1982) • 82/893/EEC (entry into force 29/12/1982) • 83/642/EEC (entry into force 19/12/83) • 83/646/EEC (entry into force 21/12/1983) • 84/643/EEC (entry into force 30/6/1984) • 84/644/EEC (entry into force 30/9/1985) • 85/320/EEC (entry into force 19/6/1985) • 85/586/EEC (entry into force 24/12/1985) • 87/231/EEC (entry into force 10/4/1987) • 87/489/EEC (entry into force 30/10/1987) • 88/406/EEC (entry into force 27/6/1988) • 89/360/EEC (entry into force 6/6/1989) • 89/469/EEC (entry into force 28/7/1989) • 89/662/EEC (entry into force 22/12/1989) • 90/422/EEC (entry into force 9/7/1990) • 90/423/EEC (entry into force 26/7/1990) • 90/425/EEC (entry into force 26/7/1990) • 91/499/EEC (entry into force 16/7/1991) • 91/687/EEC (entry into force 19/11/1992) • 92/65/EEC (entry into force 29/7/1992) • 92/102/EEC (entry into force 8/12/1992) • 94/178/EC (entry into force 23/3/1994) • 94/42/EC (entry into force 24/8/1994) • 95/25/EC (entry into force 18/10/1995) • 97/12/EC (entry into force 25/4/1997) • 98/46/EC (entry into force 15/7/1998) • 98/99/EC (entry into force 31/12/1998) • 2000/15/EC (entry into force 3/5/2000) • 2000/20/EC (entry into force 4/7/2000) Regulation (EC) • No. 3768/85 (entry into force 1/1/1986) • No. 535/2002 (entry into force 13/4/2002) • No. 1226/2002 (entry into force 29/7/2002) ▪ Replacements and additions of Articles and Annexes
Directive 72/462/EEC (entry into force 1/10/1973 Article 23 and 1/1/1976 other provisions) Health and veterinary inspection problems upon importation of bovine animals and swine and fresh meat from third countries	• This Directive applies to imports from third countries of domestic bovine animals and swine for breeding, production or slaughter and fresh meat of domestic animals • This Directive does not apply to animals intended exclusively for grazing or draft purposes • On arrival in the country of destination animals for slaughter must be taken immediately to a slaughterhouse within three working days of entry therein	Amendments – Directive • 75/379/EEC (entry into force 18/6/75) • 77/98/EEC (entry into force 1/7/1978) • 81/476/EEC (entry into force 1/7/81) • 83/91/EEC (entry into force 15/2/84) • 87/64/EEC (entry into force 1/1/1988) • 88/489/EEC (entry into force 1/1/89) • 88/657/EEC (entry into force 1/1/92) • 89/227/EEC (entry into force 30/6/90) • 90/423/EEC (entry into force 1/1/92) • 91/69/EEC (entry into force 31/12/92) • 91/266/EEC (entry into force 29/5/91) • 91/497/EEC (entry into force 24/9/91) • 91/688/EEC (entry into force 1/1/92) • 96/91/EC (entry into force 16/1/1997)

Table 2.5 (*Continued*)

Title	Main points	Comments
	• This Directive sets procedures for determining the geographical zones and the establishments from which Member States may authorise importation of live animals and fresh meat	• 97/76/EC (entry into force 16/1/1998) • 97/79/EC (entry into force 19/2/1998) ◦ Regulation (EC) No. 1452/2001 (entry into force 24/7/2001) ▪ Addition, replacement and amendment of Articles and Annexes
Directive 77/96/EEC (entry into force 1/1/1979) Examination for trichinae (*T. spiralis*) upon importation from third countries of fresh meat derived from domestic swine	• The Directive establishes a Community system for detecting the presence of trichinae in fresh pig meat and upon importation of fresh meat from third countries • Meat, the examination of which revealed no trichinae, must be marked immediately • A Member State may also admit into its territory fresh meat which has not been screened for trichinae in the exporting third country provided that the meat in question undergoes treatment by freezing	Amendments – Directive • 77/96/EEC (entry into force 1/1/1979) • 81/476/EEC (entry into force 7/7/81) • 83/91/EEC (entry into force 15/5/84) • 84/319/EEC (entry into force 1/1/85) • 89/321/EEC (entry into force 1/9/89) • 94/59/EC (entry into force 12/12/94) ◦ Regulation (EEC) No. 3768/85 (entry into force 1/1/1986) ▪ Replacements and corrections in the Articles
Directive 77/504/EEC (entry into force 1/1/1979) Pure-bred breeding animals of the bovine species	• These measures define certain rules on trade in pure-bred breeding animals of the bovine species so as to enable intra-Community trade in these animals to be progressively liberalised • Definitions (pure-bred breeding animal of the bovine species etc.) • Performance monitoring methods and methods for assessing cattles' genetic value	Amendments – Directive • 79/268/EEC (entry into force 1/1/79) • 91/174/EEC (entry into force 1/1/92) • 94/28/EEC (entry into force 12/7/94) ◦ Regulation (EEC) No. 3768/85 (entry into force 1/1/1986) ▪ Corrections and replacements in the Articles
Directive 88/407/EEC (entry into force 1/1/1990) Laying down the animal health requirements applicable to intra-Community trade in and imports of deep-frozen semen of domestic animals of the bovine species	• The Directive lays down the animal health conditions applicable to intra-Community trade in and imports from third countries of both fresh and deep-frozen semen of domestic animals of the bovine species • Definitions (semen, semen collection centre, official veterinarian, centre veterinarian, country of collection etc.) • Imports of semen from third countries are restricted to a list of authorised countries to be determined	Amendments – Directive • 90/120/EEC (entry into force 1/4/90) • 90/425/EEC (entry into force 26/7/90) • 93/60/EEC (entry into force 1/7/1994) • 2003/43/EC (entry into force 11/6/03) ▪ Corrections of definitions and replacements of Articles
Directive 88/661/EEC (entry into force 1/1/1991) Zootechnical standards applicable to breeding animals of the porcine species	• Definitions (pure-bred breeding pig, hybrid breeding pig, herd-book and register) • Performance monitoring methods for assessing pigs' genetic value • Member States may not prohibit, restrict or impede on zootechnical grounds intra-Community trade in pure-bred or hybrid breeding pigs or their semen, ova and embryos	Amendment • Regulation (EC) No. 806/2003 (entry into force 5/6/2003) ▪ Corrections in the Articles

Table 2.5 (*Continued*)

Title	Main points	Comments
Directive 89/556/EEC (entry into force 1/1/1991) Animal health conditions governing intra-Community trade in and importation from third countries of embryos of domestic animals of the bovine species	• The Directive lays down animal health conditions for trade between Member States in embryos of domestic cattle and imports from third countries • The Directive envisages a system for approving the embryo collection teams in the Member States and in third countries • Imports of embryos from third countries are restricted to a list of authorised countries to be drawn up by a procedure involving the Standing Veterinary Committee	Amendments – Directive • 90/425/EEC (entry into force 26/7/90) • 93/52/EEC (entry into force 1/1/1994) • 94/113/EEC (entry into force 11/2/94) ○ Regulation (EC) No. 806/2003 (entry into force 5/6/2003) ▪ Corrections in the Articles
Directive 90/429/EEC (entry into force 31/12/1991) Laying down the animal health requirements applicable to intra-Community trade in and imports of semen of domestic animals of the porcine species	• The Directive lays down the animal health requirements applicable to intra-Community trade in and imports from third countries of semen of animals of the porcine species • Imports of porcine semen may only be made from those third countries on the list of semen collection centres • Intra-Community trade in semen requires compliance with regulations concerning collection, processing, storage and transport as well as provisions on protection against the spread of Aujeszky's disease	Amendments • Decision 1999/608/EC (entry into force 1/10/1999) • Decision 2000/39/EC (entry into force 8/2/2000) ○ Regulation (EC) No. 806/2003 (entry into force 5/6/2003) ▪ Replacement of the Articles
Decision 1999/879/EC (entry into force 1/1/2000) The placing on the market and administration of bovine somatotropin (BST)	• This Decision is intended to regulate the marketing and use of bovine somatotropin or bovine growth hormone within the European Union • The Decision thus prohibits the placing on the market of bovine somatotropin on EU territory for the purpose of its marketing and the administration thereof to dairy cows by any means • The production or importation of bovine somatotropin in the Member States for the purposes of exporting it to third countries continues to be authorised	

Adapted from Arvanitoyannis *et al.* (2005).

covered. For the purposes of this Directive, the following definition shall apply 'pure-bred breeding sheep and goat': any sheep or goat the parents and grandparents of which are entered or registered in a flock book of the same breed and which is itself entered or registered and eligible for entry therein. Member States may not prohibit, restrict or impede on zootechnical grounds: (i) intra-Community trade in pure-bred breeding sheep and goats and the semen, ova and embryos thereof and (ii) the official approval of breeders' organisations or associations which maintain or establish flock books. The Commission shall determine before 1 January 1991: (i) the criteria for the approval of breeders' organisations and associations which maintain or establish flock books, (ii) the criteria for entry or registration in flock books, (iii) methods for monitoring performance and assessing the genetic value of pure-bred breeding sheep and goats and (iv) the criteria for the approval of a breeding animal for the purpose of using its semen, ova or embryos.

The Directive 91/68/EEC (entry into force 4/2/1991) claims that ovine and caprine animals (a) must be

identified and registered, the time limit for notifying the national systems for identifying and registering ovine and caprine animals begins running from the date of adoption of this Directive, (b) must show no clinical sign of disease when inspected by an official veterinarian, such inspection must take place during the 48 hours preceding the loading of the ovine and caprine animals, (c) do not come from a holding, nor have been in contact with animals from a holding, which is the subject of a prohibition on animal health grounds; the period of such prohibition shall last after the slaughter and/or the disposal of the last animal suffering from or susceptible to one of the diseases referred to in the following points, for at least: i) 42 days in the case of brucellosis, ii) 30 days in the case of rabies, iii) 15 days in the case of anthrax, and must not come from a holding or have been in contact with animals from a holding situated in an established protection zone and from which animals are forbidden to leave and (d) must not be the subject of animal health restrictions introducing Community measures for the control of foot-and-mouth disease. The diseases, to which this Directive applies, are foot-and-mouth disease, brucellosis (*Brucella melitensis*), contagious epididymitis (*B. ovis*), anthrax, rabies, scrapie, contagious agalactia, paratuberculosis, caseous lymphadenitis, pulmonary adenomatosis, maedi visna and aprine viral arthritis/encephalitis. An officially brucellosis (*B. melitensis*)-free ovine or caprine holding means (1) a holding: (a) in which all the animals which are susceptible to brucellosis (*B. melitensis*) have been free from clinical or any other signs of brucellosis (*B. melitensis*) for at least 12 months, (b) which contains no ovine or caprine animals which have been vaccinated against brucellosis (*B. melitensis*), save those vaccinated at least 2 years previously vaccine, (c) in which two tests separated by an interval of 6 months or more have been carried out, with negative results, on all ovine and caprine animals on the holding over 6 months of age at the time of testing and (d) in which there are only ovine or caprine animals born on the holding or which have come from an officially brucellosis-free or brucellosis-free holding under certain conditions; (2) a holding situated in an officially recognised brucellosis-free Member State or region. The representative number of animals to be tested must, for each holding, consist of the following: (i) all non-castrated male animals over 6 months old, (ii) all animals brought onto the holding since the previous test and (iii) 25% of the females which have reached the age of reproduction (i.e. which are sexually mature) or are in milk, with a minimum of 50 per holding – except in holdings where there are fewer than 50 such females, in which case all females must be tested.

The Directive 2004/68/EC (entry into force 20/5/2004) specifies that the Commission, with the assistance of the Standing Committee on the Food Chain, draws up a list of (parts of) third countries from which importations of the animals concerned are authorised. In drawing up these lists, it takes particular account of (i) the legislation of the third country and the organisation and powers of the competent authority and inspection services, (ii) the country's health status and procedures for notifying the Commission and international organisations and (iii) compliance or equivalence with the Community requirements and Community inspections carried out in the third country. Authorised third countries must guarantee that the animals have been checked by a veterinary official and comply with certain animal health conditions taking into account, in particular, the species, age and use of the animal concerned. Each consignment of animals must be accompanied by a veterinary certificate attesting that the animals concerned are hazard free and providing certain information, such as details on public health, animal health or animal welfare. Derogations may be provided depending on the destination of the animals (zoos, circuses, pet animals) or when animal movements have been prohibited, in the event of a change in the health situation of the country affected by the prohibition. Commission experts may carry out inspections in the third countries in order to verify the compliance or equivalence of the animal health rules.

Some representative points and comments (repeals, modifications, amendments) of the Directives related to specific provisions – ovine and caprine animals – are given in Table 2.6.

2.2.7 Specific provisions – poultry

The Directive 71/118/EEC (entry into force 28/3/1971) claims that it shall apply to trade in fresh meat of domestic animals of the following species: hens, turkeys, guinea fowls, ducks and geese. All parts of those animals which are fit for human consumption shall be considered to be poultry meat. All poultry meat which has not undergone any preserving process shall be considered to be fresh meat; however, for the purposes of this Directive, chilled and frozen poultry meat shall be considered to be fresh meat. Each Member State shall ensure that trade is allowed only in fresh poultry meat which meets the following requirements: (a) it has been obtained from a slaughterhouse, (b) it comes from an animal inspected ante-mortem by an official veterinarian or by assistants and considered suitable for slaughter for trade in fresh poultry meat, (c) it has been treated under satisfactory hygiene conditions, (d) it has been inspected post-mortem by an official

Table 2.6 Directives (main points and comments) related to specific provision – ovine and caprine animals.

Title	Main points	Comments
Directive 72/462/EEC (entry into force 1/10/1973 Article 23 and 1/1/1976 other provisions) Health and veterinary inspection problems upon importation of bovine animals and swine and fresh meat from third countries	• This Directive sets procedures for determining the geographical zones and the establishments from which Member States may authorise importation of live animals and fresh meat • Member States authorise importation of animals only on presentation of a certificate made out by an official veterinarian of the exporting third country • Member States ensure that immediately on arrival in the Community domestic goats and sheep are given an animal health check by an official veterinarian • On arrival in the country of destination, animals for slaughter must be slaughtered within three working days of entry therein	Amendments – Directive • 75/379/EEC (entry into force 18/6/1975) • 77/98/EEC (entry into force 1/7/1978) • 81/476/EEC (entry into force 1/7/1981) • 83/91/EEC (entry into force 15/2/1984) • 87/64/EEC (entry into force 1/1/1988) • 88/489/EEC (entry into force 1/1/1989) • 88/657/EEC (entry into force 31/12/88) • 89/227/EEC (entry into force 30/6/1990) • 90/423/EEC (entry into force 18/8/1990) • 91/69/EEC (entry into force 31/12/1992) • 91/266/EEC (entry into force 29/5/1991) • 91/497/EEC (entry into force 24/9/1991) • 91/688/EEC (entry into force 1/1/1992) • 96/91/EC (entry into force 16/1/1997) • 97/76/EC (entry into force 16/1/1998) • 97/79/EC (entry into force 19/2/1998) ○ Regulation (EC) No. 1452/2001 (entry into force 24/7/2001) ▪ Replacement, correction and addition of the Articles and the Annexes
Directive 89/361/EEC (entry into force 1/1/1991) Pure-bred breeding sheep and goats	• Definitions (pure-bred breeding sheep, pure-bred breeding goat and flock book) • Member States may not prohibit, restrict or impede on zootechnical grounds neither intra-Community trade in pure-bred breeding sheep and goats and their semen, ova and embryos nor the official approval of breeders' organisations which maintain or establish flock books	
Directive 91/68/EEC (entry into force 4/2/1991) Animal health conditions governing intra-Community trade in ovine and caprine animals	• Defining the animal health conditions governing intra-Community trade in ovine and caprine animals • Definitions (ovine or caprine animals for slaughter, ovine or caprine animals for breeding and fattening etc.) • Rules on control programmes for certain diseases including scrapie, maedi visna, caprine viral arthritis/encephalitis, contagious agalactia and paratuberculosis • A registration and approval system has been organised to ensure adequate sanitary conditions during trading and during the time spent by animals in their own premises	Amendments – Decisions • 94/164/EC (entry into force 2/3/1994) • 94/953/EC (entry into force 1/1/1995) • 2001/298/EC (entry into force 31/7/01) • 2001/10/EC (entry into force 20/6/01) • 2002/261/EC (entry into force 6/5/02) • 2003/708/EC (entry into force 13/10/03) • 2003/50/EC (entry into force 9/7/2003) • 2004/554/EC (entry into force 1/6/2004) ○ Regulation (EC) No. 806/2003 (entry into force 5/6/2003) ▪ Replacement of the Annexes and addition in the Articles
Directive 2004/68/EC (entry into force 20/5/2004) Laying down animal health rules for the importation into and transit through the Community of certain live ungulate animals	• This Directive lays down the animal health rules governing the importation from third countries and transit through the European Union (EU) of certain live ungulates • List of authorised third countries • Guarantees from the third countries • Inspection in third countries • This Directive revises Community law, taking account of the evolution of the international standards of the Office International des Épizooties (OIE)	Repeal • Directive 72/462/EEC

Adapted from Arvanitoyannis *et al.* (2005).

veterinarian or by assistants and found to be fit for human consumption, (e) it bears a health marking, (f) it has been stored after post-mortem inspection under satisfactory hygiene conditions in slaughterhouses or in cold stores and (g) it has been suitably packed and transported under satisfactory hygiene conditions conforming to certain requirements. The following shall be excluded from trade: (a) fresh poultry meat treated with hydrogen peroxide or other bleaching substances or with natural or artificial colouring matters, (b) fresh poultry meat treated with antibiotics, preservatives or tenderisers and (c) fresh poultry meat treated with flavouring substances. All approved slaughterhouses shall be registered on a list and each shall be given a veterinary approval number. Each Member State shall communicate the list of approved slaughterhouses and their veterinary approval numbers to the other Member States and the Commission and notify them of any withdrawal of approval. Veterinary experts must be nationals of a Member State other than those involved in the dispute. A Member State may, if there is a danger that animal diseases may be spread by the introduction into its territory of fresh poultry meat from another Member State, take the following measures: (a) in the event of an outbreak of an epizootic disease in the other Member State, temporarily prohibit or restrict the introduction of fresh poultry meat from the affected areas of that Member State and (b) if an epizootic disease becomes widespread or if there is an outbreak of another serious contagious or infectious animal disease, temporarily prohibit or restrict the introduction of fresh poultry meat from the entire territory of that State.

The Directive 89/437/EEC (entry into force 31/12/1991) prescribes the hygiene and health requirements concerning the production and the placing on the market of egg products for direct human consumption or for the manufacture of foodstuffs. However, this Directive shall not apply to (i) finished foodstuffs manufactured from egg products and (ii) egg products which are obtained in small-scale enterprises and which, without having undergone any treatment, are used for the manufacture of foodstuffs intended for direct sale, without any intermediary, to the consumer or consumed on the spot immediately after having been prepared. The following definition shall also apply to 'egg products': products obtained from eggs, their various components or mixtures thereof, after removal of the shell and membranes, intended for human consumption, they may be partially supplemented by other foodstuffs or additives; they may be liquid, concentrated, dried, crystallised, frozen, quick-frozen or coagulated. Member States shall ensure that only egg products which meet the following general requirements are produced as foodstuffs or used in the manufacture of foodstuffs: (a) they must have been obtained from hens', ducks', geese's, turkey's, guinea fowl's or quail's eggs, but not a mixture of eggs of different species, (b) they must bear an indication of the percentage of egg ingredients they contain when they are partially supplemented by other foodstuffs or by additives, (c) they must have been treated and prepared in an establishment which satisfies the requirements of this Directive, (d) they must have been prepared under hygienic conditions, (e) they must have undergone a treatment process which enables them to meet inter alia the analytical specifications, (f) they must have undergone a health check, (g) they must have been packed in accordance with this Directive, (h) they must be stored and transported in accordance with this Directive, (i) they must bear the mark of wholesomeness where intended for direct human consumption. Establishments must possess at least: (1) appropriate materials (waterproof flooring; smooth, durable and impermeable walls etc.) in areas where eggs are stored and where egg products are manufactures or stored, (2) an appropriate number of changing rooms, with smooth, impermeable and washable walls and floors, wash basins and flush lavatories, (3) a separate area and adequate facilities for cleaning and disinfecting fixed and mobile containers and tanks, (4) facilities for the supply of exclusively potable water within the meaning of Council directive 80/778/EEC relating to the quality of water intended for human consumption, (5) appropriate equipment for protection against pests such as insects and rodents and (6) equipment, couplings and instruments or their surfaces which are intended to come into contact with egg products must be made of smooth material which is easy to wash, clean and disinfect.

Another Directive (90/539/EEC, entry into force 1/1/1992) specifies that hatching eggs, day-old chicks, breeding poultry and productive poultry must come from (1) establishments which fulfil the following requirements: (a) they must be approved and given a distinguishing number by the competent authority, (b) they must not, at the time of consignment, be the subject of any animal health restrictions applicable to poultry and (c) they must not be located in an infected area; (2) a flock which, at the time of consignment, presents no clinical sign or suspicion of disease. However, poultry and hatching eggs must have come from flocks which (i) have been held in the Community since hatching or for at least 3 months, (ii) present no clinical signs of a contagious poultry disease at the time of consignment, (iii) if there is a vaccination requirement, satisfy the vaccination conditions, (iv) are not the subject of any animal health restrictions applicable

to poultry, (v) are not located in an area infected with avian influenza or Newcastle disease, to be defined in the framework of the measures to combat these diseases to be adopted and (vi) have been found negative in serological tests for *Salmonella* pullorum and *Salmonella* gallinarum antibodies. The status of Member States or regions of Member States from the point of view of Newcastle disease shall be established by the Commission at the latest 6 months before the date on which the Member States must conform to this Directive. The elements to be taken into consideration for determining this status shall satisfy the following criteria: (i) no Newcastle disease shall have been detected in the poultry for at least the preceding 12 months, (ii) vaccination against Newcastle disease in the poultry shall not have been authorised for at least the preceding 12 months, (iii) all breeding flocks shall have been monitored at least once a year for the presence of Newcastle disease and (iv) the holdings shall contain no poultry which have been vaccinated against Newcastle disease. Where a Member State draws up or has drawn up a voluntary or compulsory control programme for a disease to which poultry are susceptible, it may present the programme to the Commission, outlining in particular: (i) the distribution of the disease in its territory, (ii) the reasons for the programme, taking into consideration the importance of the disease and the programme's likely benefit in relation to its cost, (iii) the geographical area in which the programme will be implemented, (iv) the status categories to be applied to poultry establishments, the standards which must be attained in each category and the test procedures to be used, (v) the programme monitoring procedures, (vi) the action to be taken if, for any reason, an establishment loses its status and (vii) the measures to be taken if the results of the tests carried out in accordance with the provisions of the programme are positive.

According to Directive 92/116/EEC (entry into force 1/1/1994), the model health certificate for fresh poultry meat should contain the following points: (i) identification of meat, (ii) origin of meat, (iii) destination of meat and (iv) attestation. Fresh poultry meat must meet the following conditions: carcases and offal must (a) come from an animal inspected before slaughter and considered suitable for slaughter for the placing on the market of fresh poultry meat, (b) have been obtained from an approved slaughterhouse subject to own-checks and to checks by the competent authority, (c) have been treated under satisfactory hygiene conditions, (d) have been inspected post-mortem and not have been found unfit for human consumption, (e) be given a health marking on the understanding that such marking is not necessary for carcases that are to be cut in the same establishment, (f) after post-mortem inspection have been handled and stored under satisfactory hygiene conditions, (g) have been suitably packaged, (h) have been transported in accordance with this Directive, (i) be accompanied during their transport by either a commercial document or health certificate. Member States shall ensure that (a) all farms delivering poultry of the species to slaughterhouses are kept under veterinary supervision and (b) it is guaranteed that (i) in approved slaughterhouses at least one official veterinarian is present throughout the post-mortem inspection, (ii) in approved cutting plants a member of the inspection team is present at least once a day when meat is being worked on, to check the general hygiene of the plant and the register of fresh meat entering and leaving it and (iii) in cold stores, a member of the inspection team referred to in this Directive is regularly present. Fresh poultry meat can be imported into the Community only if it comes from (a) third countries or parts of third countries listed in accordance with this Directive and (b) establishments for which the competent authority of the third country has provided the Commission with guarantees that these establishments meet the requirements of this Directive.

A summary of the Directives focused on specific provisions – poultry – is given in Table 2.7.

2.2.8 Specific provisions – meat and meat-based production

The Directive 72/461/EEC (entry into force 31/12/1977) applies to intra-Community trade in fresh meat of domestic bovine animals, swine, sheep, goats and solipeds. All parts of these animals which are fit for human consumption shall be considered to be meat. All meat which has not undergone any preserving process shall be considered as fresh meat; however, for the purposes of this Directive chilled and frozen meat shall be considered to be fresh meat. Only fresh meat which fulfils the following requirements may be sent from the territory of one Member State to the territory of another Member State: (a) meat obtained from domestic sheep, goats or solipeds must come from animals which have stayed in the territory of the Community for at least 21 days immediately prior to slaughter or from birth in the case of animals less than 21 days old, (b) the meat must not have been obtained from animals which come from a holding or area which for health reasons is subject to prohibition on animal health problems affecting intra-Community trade in bovine animals and swine, as a result of the outbreak of foot-and-mouth disease, swine fever or contagious swine paralysis (Teschen disease) to which the animals in question are susceptible and (c) the meat must not be obtained from slaughterhouses in which cases of

Table 2.7 Directives (main points and comments) with regard to specific provisions – poultry.

Title	Main points	Comments
Directive 71/118/EEC (entry into force 28/3/1971) Health problems affecting trade in fresh poultry meat	• This Directive applies to trade in fresh meat of domestic animals of the following species: hens, turkeys, guinea fowls, ducks and geese • All poultry meat which has not undergone any preserving process shall be considered to be fresh meat; however, chilled and frozen poultry meat shall be considered to be fresh meat • Provisions concerning intra-Community trade and trade within Member States • Provisions concerning only intra-Community trade • Hygiene requirements for slaughterhouses	Amendment • Directive 92/116/EEC (entry into force 15/3/1993) ▪ Replacement and addition of this Directive
Directive 89/437/EEC (entry into force 31/12/1991) Hygiene and health problems affecting the production and the placing on the market of egg products	• The Directive covers health problems affecting the production and marketing of egg products for direct human consumption or for use in the manufacture of foodstuffs • Member States are required to comply with a number of similar requirements with respect to the manufacture, handling, packaging, storage and transport of egg products • Member States must draw up a list of approved establishments	Amendments – Directive • 89/662/EEC (entry into force 1/7/1992) • 91/684/EEC (entry into force 31/12/91) ▪ Replacement of Annex and Articles
Directive 90/539/EEC (entry into force 1/1/1992) Animal health conditions governing intra-Community trade in, and imports from third countries of, poultry and hatching eggs	• Defining the animal health conditions governing intra-Community trade in and imports from third countries of poultry and hatching eggs • This Directive does not apply to poultry in trade for exhibitions, shows or contests • Definition (poultry, hatching eggs, day-old chicks etc.) • Rules for intra-Community trade • Rules for imports from third countries	Amendments – Directive • 91/494/EEC (entry into force 1/5/1992) • 91/496/EEC (entry into force 1/7/1992) • 92/65/EEC (entry into force 1/1/1994) • 92/369/EEC (entry into force 25/6/1992) • 93/120/EC (entry into force 1/1/1995) • 1999/90/EC (entry into force 1/7/2000) • 2000/505/EC (entry into force 29/8/2000) • 2001/867/EC (entry into force 1/1/2002) ▪ Replacement in Articles and Annexes
Directive 92/116/EEC (entry into force 1/1/1994) Health problems affecting trade in fresh poultry meat	• This Directive lays down health rules for the production and placing on the market of fresh poultry meat • This Directive does not apply to the cutting and storage of fresh poultry meat in retail shops or in premises adjacent to sales points • Fresh poultry meat to be marketed must meet certain requirements • Commission veterinary experts will be required to make on-the-spot checks • Each Member State will draw up a list of its approved establishments	

Adapted from Arvanitoyannis *et al.* (2005).

foot-and-mouth disease, swine fever or contagious swine paralysis (Teschen disease) have been recorded. Should there be an outbreak of one of these diseases, the Member States shall ensure that no meat suspected to be contaminated forms part of intra-Community trade. If there is a danger that animal diseases may be spread by the introduction into its territory of fresh meat from another Member State, take the following

measures: (a) in the event of an outbreak of an epizootic disease in the other Member State, it may temporarily prohibit or restrict the introduction of meat from the affected areas of that Member State and (b) if an epizootic disease becomes widespread or if there is an outbreak of another serious contagious or infections animal disease, it may temporarily prohibit or restrict the introduction of meat from the entire territory of that State.

The Directive 80/215/EEC (entry into force 31/12/1980) claims that a Member State may take the following measures if there is a danger that animal diseases may be spread by the introduction of meat products from another Member State into its territory: (a) in the event of an outbreak of classical foot-and-mouth disease, classical swine fever or Teschen disease in the other Member State, the introduction of products prepared from the meat of animals which are susceptible to these diseases, other than products which have undergone one of the treatments referred to the Directive, may be temporarily prohibited or restricted from those parts of the territory of the Member State in which the disease has appeared and (b) if an epizootic disease becomes widespread or if there is an outbreak of another serious and contagious or infectious animal disease, the introduction from the entire territory of that State, of products prepared from the meat of animals which are susceptible to these diseases may be temporarily prohibited or restricted. Meat products intended for intra-Community trade, which are prepared in whole or in part from or with fresh meat may enter intra-Community trade if they have also undergone one of the following forms of treatment: (a) heat treatment in a hermetically sealed container, with an F_c value of 3–7 or more and (b) where the fresh meat has been obtained from animals which do not come from an infected holding subject to prohibition measures of this Directive: (i) heat treatment different from that referred to in (a) in which the internal temperature is raised to at least 70°C or (ii) treatment consisting in natural fermentation and maturation of not less than 9 months for boned or boneless hams weighing not less than 5.75 kg and having the following characteristics: a_w value of not more than 0.793 and pH value of not more than 6.

According to Directive 91/497/EEC (entry into force 1/1/1993), each Member State shall ensure that carcases, half carcases or half carcases cut into no more than three wholesale cuts, and quarters (a) have been obtained in a slaughterhouse meeting the conditions laid down in this Directive, (b) come from a slaughter animal inspected ante-mortem by an official veterinarian, as a result of such inspection, for slaughter for the purposes of this Directive, (c) have been treated under satisfactory hygiene conditions, (d) have been inspected post-mortem by an official veterinarian and do not show any change except for traumatic lesions which occurred shortly before slaughter or localised malformations or changes, provided that it is established, if necessary by appropriate laboratory tests, that these lesions, malformations or changes do not render the carcase and offal unfit for human consumption or dangerous to human health, (e) bear a health mark, (f) are accompanied during transportation by the health certificate issued by the official veterinarian, (g) are stored in accordance with the Annex of this Directive after post-mortem inspection under satisfactory hygiene conditions in establishments approved and supervised in accordance with this Directive, (h) are transported under satisfactory hygiene conditions. Cuts or small pieces of boned meat (a) are boned or cut in a cutting plant meeting the conditions laid down in this Directive, (b) are boned or cut and come from fresh meat from Community or from third countries, (c) have been stored under conditions which comply with this Directive, (d) have been checked by an official veterinarian and (e) meet the wrapping and packaging requirements. However, this Directive shall not apply to (a) fresh meat intended for uses other than human consumption, (b) fresh meat intended for exhibition, special studies or analysis, provided that official control makes it possible to ensure that the meat is not used for human consumption and that, when the exhibition is over or when the special studies or the analysis have been carried out, the meat, with the exception of that used for the purposes of analysis, is destroyed and (c) fresh meat intended exclusively as supplies for international organisations.

All EU Member States shall prohibit (96/22/EC, entry into force 23/5/1996): (a) the placing on the market of stilbenes, stilbene derivatives, their salts and esters and thyrostatic substances for administering to animals of all species, (b) the placing on the market of beta-agonists for administering to animals the flesh and products of which are intended for human consumption, (c) the administering to a farm or aquaculture animal, by any means whatsoever, of substances having a thyrostatic, oestrogenic, androgenic or gestagenic action and of beta-agonists, (d) the holding, except under official control, of animals referred to in (c) on a farm, the placing on the market or slaughter for human consumption of farm animals or of aquaculture animals which contain the substances referred to in (c) or in which the presence of such substances has been established, unless proof can be given that the animals in question have been treated in accordance with this Directive, (e) the placing on the market for human consumption of aquaculture animals to which substances have been administered and of processed products derived from such animals, (f) the

placing on the market of meat of the animals referred to in (d), (g) the processing of the meat referred to in (f). The following may not, however, be authorised: (a) the following hormonal products: (i) products acting as a deposit, (ii) products with a withdrawal period of more than 15 days after the end of treatment and (iii) products which were authorised under rules, whose conditions of use are not known, for which no reagents or equipment exist for use in the analytical techniques for detecting the presence of residues in excess of the permitted limits; (b) veterinary medicinal products containing beta-agonists which have a withdrawal period of more than 28 days after the end of treatment. Third countries whose legislation authorises the placing on the market and administration of stilbenes, stilbene derivatives, their salts and esters, or of thyrostatic substances for administering to animals of all species may not appear on any of the lists of countries provided for under Community legislation from which Member States are authorised to import farm or aquaculture animals or meat or products obtained from such animals. Member States shall also prohibit the importation from third countries on any of the lists of (a) farm or aquaculture animals: (i) to which products or substances have been administered by any means whatsoever and (ii) to which substances or products have been administered, unless those substances or products were administered in compliance with the provisions and requirements laid down in this Directive (96/22/EC) and the withdrawal periods allowed in international recommendations have been observed and (b) meat or products obtained from the importation of animals.

The titles, main points and comments of the EU Directives about specific provisions – meat and meat-based production – are summarised in Table 2.8.

2.2.9 Specific provisions – fish and fishery products

According to Directive 91/67/EEC (entry into force 1/1/1993), the placing on the market of aquaculture animals shall be subject to the following general requirements: (a) they must show no clinical signs of disease on the day of loading, (b) they must not be intended for destruction or slaughter under a scheme for the eradication of a disease and (c) they must not come from a farm which is subject to a prohibition for animal health reasons and must not have been in contact with animals from such a farm. Aquaculture products being placed on the market for breeding purposes (eggs and gametes) must originate from animals which satisfy the requirements laid down in this Directive. Aquaculture products being placed on the market for human consumption must originate from animals which satisfy the requirements laid down in this Directive. The placing on the market of live fish belonging to the susceptible species, their eggs or gametes, shall be subject to the following additional guarantees: (a) where they are to be introduced into an approved zone, they must be accompanied by a movement document corresponding or certifying that they come from an approved zone or an approved farm. Additional guarantees to be met for the introduction into an approved zone of fish coming from an approved farm situated in a non-approved zone shall be fixed. Pending that decision, national rules shall continue to apply subject to compliance with the general provisions of the Treaty, (b) where they are to be introduced into a farm, although not situated in an approved zone, they must be accompanied by a movement document corresponding or certifying that they come respectively from an approved zone or from a farm of the same health status as the farm of destination. Live molluscs susceptible to the diseases of a list must be delivered either for direct human consumption or to the preserving industry and shall not be relaid unless they originate in an approved farm in a non-approved coastal zone or they are temporarily immersed in storage ponds or sterilisation centres which are specially equipped and approved for that purpose by the competent authority and include in particular a system for the treatment and disinfection of residual water. The conditions for such approval will be determined by the Commission. Aquaculture animals and products must come from third countries or parts thereof appearing on a list drawn up by the Commission. In deciding whether a third country or part thereof may appear on the list referred to in the Directive, particular account shall be taken of (a) the state of health of the aquaculture animals, particular attention being paid to exotic diseases and the environmental health situation in the third country which might endanger the health of livestock in the Member States, (b) the regularity and rapidity of the information supplied by the country relating to the existence of infectious or contagious diseases of aquaculture animals in its territory, in particular those diseases mentioned in the list of the International Office of Epizootics, (c) the rules of the third country on the prevention and control of diseases of aquaculture animals, (d) the structure of the official services in the third country and their powers, (e) the organisation and implementation of measures to prevent and control infectious or contagious diseases of aquaculture animals and (f) assurances which the third country may provide concerning the rules laid down in this Directive.

Following the Directive 91/492/EEC (entry into force 14/10/1991), the placing on the market of live bivalve molluscs for immediate human consumption shall be subject to the following conditions: (a) they must originate from production areas which comply

Table 2.8 Directives (main points and comments) for specific provisions – meat and meat-based production.

Title	Main points	Comments
Directive 72/461/EEC (entry into force 31/12/1977) Health problems affecting intra-Community trade in fresh meat	• This Directive shall apply to intra-Community trade in fresh meat of domestic bovine animals, swine, sheep, goats and solipeds • The animals from which the fresh meat is taken must have been in the Community for at least 21 days before slaughter • Intra-Community trade in fresh meat of animals coming from an area in which health restrictions apply is forbidden • The meat must be obtained in slaughterhouses in which no disease has been recorded	Amendments – Directive • 74/387/EEC (entry into force 18/7/1974) • 75/379/EEC (entry into force 18/6/1975) • 77/98/EEC (entry into force 31/12/1982) • 80/213/EEC (entry into force 31/12/80) • 80/1099/EEC (entry into force 1/7/1981) • 81/476/EEC (entry into force 7/7/1981) • 83/646/EEC (entry into force 2/1/1984) • 84/336/EEC (entry into force 30/6/1984) • 84/643/EEC (entry into force 31/12/84) • 85/332/EEC (entry into force 1/1/1986) • 87/64/EEC (entry into force 1/1/1988) • 87/231/EEC (entry into force 31/12/87) • 87/489/EEC (entry into force 31/12/88) • 89/662/EEC (entry into force 31/12/92) • 91/266/EEC (entry into force 21/5/1991) • 91/687/EEC (entry into force 1/7/1992) • 92/118/EEC (entry into force 30/6/1996) ◦ Regulation (EEC) No. 3768/85 (entry into force 20/1/1986) ▪ Measures relating to swine vesicular disease, classical swine fever and African swine fever
Directive 80/215/EEC (entry into force 31/12/1980) Animal health problems affecting intra-Community trade in meat products	• Defining common rules in order to eliminate disparities between Member States concerning health rules affecting meat products • The rules applicable to fresh meat must be applied to certain meat products in case of preventing animal diseases • If an epizootic disease becomes widespread or if there is an outbreak of another serious animal disease, the introduction of products prepared from the meat of animals which are susceptible to these diseases may be prohibited or restricted	Amendments – Directive • 80/215/EEC (entry into force 31/12/80) • 80/1100/EEC (entry into force 1/7/1981) • 81/476/EEC (entry into force 7/7/1981) • 85/321/EEC (entry into force 1/1/1986) • 87/491/EEC (entry into force 1/1/1988) • 88/660/EEC (entry into force 1/4/1989) • 89/662/EEC (entry into force 31/12/92) • 91/687/EEC (entry into force 1/7/1992) ◦ Regulation (EEC) No. 3768/85 (entry into force 1/1/1986) ▪ Measures relating to swine vesicular disease, classical swine fever and African swine fever
Directive 91/497/EEC (entry into force 1/1/1993) Health problems affecting intra-Community trade in fresh meat to extend it to the production and marketing of fresh meat	• The Directive lays down the health conditions applicable to the production and placing on the market of fresh meat intended for human consumption from domestic bovine animals, pigs, sheep, goats and domestic solipeds • Definitions (meat, fresh meat, carcase, establishment etc.) • Provisions concerning health requirements for the placing on the market of fresh meat • Provisions on meat and animal carcases declared unfit for human consumption by the official veterinarian • Provisions on residue tests carried out on animals or their meat	Amendments • Directive 95/23/EC (entry into force 1/12/1995) ◦ Regulation (EC) No. 806/2003 (entry into force 5/6/2003) ▪ Amending a number of technical points which have caused problems of practical application

Table 2.8 (*Continued*)

Title	Main points	Comments
Directive 96/22/EC (entry into force 23/5/1996) The prohibition on the use in stockfarming of certain substances having a hormonal or thyrostatic action and of beta-agonists	• The purpose of the Directive is to regulate the use in meat of substances having a hormonal or thyrostatic action and of beta-agonists with a view to protecting consumer health and safeguarding the quality of foodstuffs of animal origin • The Directive prohibits the placing on the market of thyrostatic substances, stilbenes, stilbene derivatives, their salts and esters etc. • It provisionally prohibits the administration of five hormones to animals intended for human consumption: progesterone, testosterone, trenbolone acetate, zeranol and melengestrol acetate	Amendment • Directive EU 2003/74/EC (entry into force 14/10/2003) ▪ Replacements in the Articles Repeals – Directive ○ 81/602/EEC from 1/7/1997 ○ 88/146/EEC from 1/7/1997 ○ 88/299/EEC from 1/7/1997

Adapted from Arvanitoyannis *et al*. (2005).

with the requirements laid down in this Directive, in the case of Pectinidae, this provision shall apply only to aquaculture products, (b) they must have been harvested and transported from the production area to a dispatch centre, sterilisation centre, relaying area or processing plant under the conditions laid down in this Directive, (c) where provided for in this Directive, they must have been relaid in suitable areas approved for that purpose, (d) they must have been handled hygienically, and where appropriate, they must have been purified in establishments approved for that purpose, (e) they must comply with the criteria set out in this Directive, (f) health controls must have been carried out, (g) they must have been appropriately wrapped, (h) they must have been stored and transported under satisfactory conditions of hygiene and (i) they must bear a health mark. Member States shall ensure that persons handling live bivalve molluscs during their production and placing on the market shall adopt all measures necessary to comply with the requirements of this Directive. Persons responsible for dispatch and sterilisation centres shall in particular ensure that (i) representative numbers of samples for laboratory examination are regularly taken and analysed in order to establish an historical record on the basis of the areas where batches come from and of the health quality of the live bivalve molluscs both before and after handling at a dispatch centre or sterilisation centre and (ii) a register is kept for the permanent record of the results of the various checks and kept for presentation to the competent authority. Provisions applied to imports of live bivalve molluscs from third countries shall be at least equivalent to those governing the production and placing on the market of Community products. The location and the boundaries of production areas must be fixed by the competent authority in such a way as to identify the areas from which live bivalve molluscs (a) can be collected for direct human consumption, (b) can be collected but only placed on the market for human consumption after treatment in a sterilisation centre, after relaying. Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three-dilution MPN-test of 6000 faecal coliforms per 100 g of flesh or 4600 *Escherichia coli* per 100 g of flesh in 90% of samples, (c) can be collected but placed on the market only after relaying over a long period (at least 2 months), whether or not combined with sterilisation, or after intensive sterilisation for a period to be fixed, so as to meet the requirements under (a). Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three-dilution MPN-test of 60,000 faecal coliforms per 100 g of flesh. Any change in the demarcation of production areas and the temporary or definitive closure thereof must be immediately announced by the competent authority to those affected by this Directive and in particular to producers and operators of sterilisation and dispatch centres. Centres must have at least: (1) appropriate buildings, durable walls etc on premises where bivalve mollusks are handled or stored, (2) an appropriate number of changing rooms, wash basins and lavatories, (3) adequate equipment for washing tools, containers and equipment, (4) facilities for the supply and, where appropriate, storage of exclusively potable water within the meaning of Council Directive 80/778/EEC relating to the quality of water intended for human consumption or facilities for supply of clean sea water, (5) equipment and instruments or their surfaces which are intended

to come into contact with bivalve mollusks must be made of corrosion-resistant material which is easy to wash and clean repeatedly.

According to Directive 91/493/EEC (entry into force 1/1/1993), the placing on the market of aquaculture products shall be subject to the following conditions: (a) they must have been slaughtered under appropriate conditions of hygiene. They must not be soiled with earth, slime or faeces. If not processed immediately after having been slaughtered, they must be kept chilled and (b) they must have been handled and, where appropriate, packaged, prepared, processed, frozen, defrosted or stored hygienically in establishments approved in accordance with this Directive and they must have been stored and transported under satisfactory conditions of hygiene. The placing on the market of the following products shall be forbidden: (i) poisonous fish of the following families: Tetraodontidae, Molidae, Diodontidae, Canthigasteridae and (ii) fishery products containing biotoxins such as ciguatera toxins or muscle-paralysing toxins. When fixing the import conditions of fishery products, particular account shall be taken of (a) the legislation of the third country, (b) the organisation of the competent authority of the third country and of its inspection services, the powers of such services and the supervision to which they are subject, as well as their facilities for effectively verifying the implementation of their legislation in force, (c) the actual health conditions during the production, storage and dispatch of fishery products intended for the Community and (d) the assurances which a third country can give on the compliance with the standards. Areas used for the preparation and processing or freezing/quick-freezing of fishery products must have (a) a non-slip floor that is also easy to clean and disinfect and equipped for easy drainage of water. Structures and fixtures must have limber holds that are large enough not to be obstructed by fish waste and to allow water to drain freely, (b) walls and ceilings that are easy to clean, particularly where there are pipes, chains or electricity conduits, (c) the hydraulic circuits must be arranged or protected in such a way as to ensure that it is not possible for any leakage of oil to contaminate fishery products, (d) adequate ventilation and, where necessary, proper vapour extraction, (e) adequate lighting, (f) appliances for cleaning and disinfecting tools, equipment and fittings and (g) appliances for cleaning and disinfecting the hands with taps that are not hand-operable and with single use towels. Conditions for frozen products, especially plants must have (a) freezing equipment sufficiently powerful to achieve a rapid reduction in the temperature so that the temperatures laid down to in this Directive can be obtained in the product and (b) freezing equipment sufficiently powerful to keep products in storage rooms at a temperature not exceeding those laid down in this Directive, whatever the ambient temperature may be. However, for technical reasons related to the method of freezing and to the handling of such products, for whole fish frozen in brine and intended for canning, higher temperatures than those laid down in this Directive are acceptable although they may not exceed $-9^{\circ}C$.

The Directive 92/48/EEC (entry into force 1/1/1993) makes clear general hygiene conditions applicable to fishery products on board fishing vessels: (1) The sections of vessels or the containers reserved for the storage of fishery products must not contain objects or products liable to transmit harmful properties or abnormal characteristics to the foodstuffs. These sections or containers must be so designed as to allow them to be cleaned easily and to ensure that melt water cannot remain in contact with the fishery products. (2) When used, the sections of vessels or the containers reserved for the storage of fishery products must be completely clean and, in particular, must not be capable of being contaminated by the fuel used for the propulsion of the vessel or by bilge water. (3) As soon as they are taken on board, the fishery products must be protected from contamination and from the effects of the sun or any other source of heat. (4) The fishery products shall be handled and stored in such a way as to prevent bruising. The use of spiked instruments shall be tolerated for the moving of large fish or fish which might injure the handler, provided the flesh of these products is not damaged. (5) Fishery products other than those kept alive must undergo cold treatment as soon as possible after loading. However, in the case of fishing vessels where cooling is not possible from a practicable point of view, the fishery products must not be kept on board for more than 8 hours. (6) Ice used for the chilling of products must be made from drinking water or clean sea water. Before use, it must be stored under conditions which prevent its contamination. (7) After the fishery products have been unloaded, the containers, equipment and sections of vessels which are directly in contact with the fishery products must be cleaned with drinking water or clean sea water. (8) Where fish is headed and/or gutted on board, such operations must be carried out hygienically and the products must be washed immediately and thoroughly with drinking water or clean sea water. The viscera and parts which may pose a threat to public health must be removed and set apart from products intended for human consumption. Livers and roes intended for human consumption must be refrigerated or frozen. (9) Equipment used for gutting, heading and the removal of fins, and containers and equipment in contact with the fishery products, must be made of or coated with a material which is waterproof, resistant

to decay, smooth and easy to clean and disinfect. When used they must be completely clean. (10) Staff assigned to the handling of fishery products shall be required to maintain a high standard of cleanliness for themselves and their clothes.

According to the Decision 97/296/EC (entry into force 1/7/1997), the list of countries and territories from which importation of fishery products in any form intended for human consumption is authorised. The countries are United Arab Emirates, Antigua and Barbuda, Albania, Netherlands Antilles, Argentina, Australia, Bangladesh, Bulgaria, Brazil, Belize, Canada, Switzerland, Ivory Coast, Chile, China, Colombia, Costa Rica, Serbia and Montenegro, Cuba, Cape Verde, Ecuador, Egypt, Falkland Islands, Gabon, Ghana, Greenland, Gambia, Guinea Conakry, Guatemala, Guyana, Hong Kong, Honduras, Croatia, Indonesia, India, Iran, Jamaica, Japan, Kenya, South Korea, Kazakhstan, Sri Lanka, Morocco, Madagascar, Mauritania, Mauritius, Maldives, Mexico, Malaysia, Mozambique, Namibia, New Caledonia, Nigeria, Nicaragua, New Zealand, Oman, Panama, Peru, Papua New Guinea, Philippines, French Polynesia, St. Pierre and Miquelon, Pakistan, Romania, Russia, Saudi Arabia, Seychelles, Singapore, Senegal, Suriname, El Salvador, Thailand, Tunisia, Turkey, Taiwan, Tanzania, Uganda, Uruguay, Venezuela, Vietnam, Yemen, Mayotte, South Africa, Zimbabwe, Armenia, Angola, Azerbaijan, Benin, Bahamas, Belarus, Republic of Congo, Cameroon, Algeria, Eritrea, Fiji, Grenada, Israel, Myanmar, Solomon Islands, St. Helena, Togo and the United States of America.

The Regulation (EC) No. 104/2000 (entry into force 2/2/2000) states for the purposes of this Regulation, *producer organisation* means any legal entity: (a) set up on the own initiative of a group of producers of one or more of the products, in case of frozen, treated or processed products, as the operations in question have been carried out on board fishing vessels, (b) established for the purpose of ensuring that fishing is carried out along rational lines and that conditions for the sale of the members' products are improved, by taking such measures as will encourage the planning of production, promote the concentration of supply, stabilise prices, encourage fishing methods and (c) the rules of association of which require its producer members, in particular to apply to fishing production and marketing. Member States shall carry out appropriate checks to ensure that each producer organisation fulfils the obligations and shall apply the following penalties in the event that these obligations are not fulfilled: (a) where a producer organisation has failed to draw up an operational programme for the fishing year, it shall not receive any of the financial assistance granted for intervention operation carried out under title for the fishing year concerned and (b) where a producer organisation has not implemented the measures provided for in its operational programme, then for the fishing year concerned: (i) only 75% of the financial assistance shall be granted for intervention operations carried out under title for the first instance of non-implementation, (ii) only 50% of the above financial assistance shall be granted for the second instance and (iii) none of the above financial assistance shall be granted after any further instance.

All the Directives/Regulations related to specific provisions – fish and fishery products – are given in Table 2.9.

2.2.10 Contamination from substances with hormonal action and other substances

According to Directive 96/22/EC (entry into force 23/5/1996), Member States shall prohibit: (a) the placing on the market of stilbenes, stilbene derivatives, their salts and esters and thyrostatic substances for administering to animals of all species and (b) the placing on the market of beta-agonists for administering to animals, the flesh and products of which are intended for human consumption. They shall, also, prohibit (i) the administering to a farm or aquaculture animal of substances having a thyrostatic, androgenic or gestagenic action and of beta-agonists, (ii) the holding of animals on a farm, the placing on the market or slaughter for human consumption of farm animals or of aquaculture animals which contain the substances referred or in which the presence of such substances has been established, (iii) the placing on the market for human consumption of aquaculture animals to which substances have been administered and of processed products derived from such animals, (iv) the placing on the market of specific animals and (v) the processing of specific kinds of meat. Member States may authorise: (1) the administering to farm animals, for therapeutic purposes, of oestradiol 17α, testosterone and progesterone and derivatives and (2) the administering for therapeutic purposes of authorised veterinary medicinal products containing: (i) allyl trenbolone, administered orally, or beta-agonists to Equidae and pets and (ii) beta-agonists, in the form of an injection to induce tocolysis in cows when calving. The official checks are carried out by the competent national authorities without prior notice. Member States shall also prohibit the importation from third countries of: (a) farm or aquaculture animals to which products or substances referred have been administered by any means whatsoever or to which substances or products referred have been administered, unless those substances or products were administered in compliance with the provisions and requirements laid down and

Table 2.9 Directives (main points and comments) focused on specific provisions – fish and fishery products.

Title	Main points	Comments
Directive 91/67/EEC (entry into force 1/1/1993) The animal health conditions governing the placing on the market of aquaculture animals and products	• This Directive creates a framework designed to overcome obstacles to trade in aquaculture animals while at the same time avoiding the spread of infectious diseases, particularly in disease-free regions of the European Union. • Aquaculture animals and products must come from third countries or parts thereof appearing on a list	Amendments – Directive • 93/54/EEC (entry into force 30/6/1994) • 95/22/EC (entry into force 31/12/1995) • 97/79/EC (entry into force 19/2/1998) • 98/45/EC (entry into force 3/7/1998) ▪ Changes in the Articles and Annexes
Directive 91/492/EEC (entry into force 14/10/1991) Laying down the health conditions for the production and the placing on the market of live bivalve molluscs	• This Directive applies to echinoderms, tunicates and marine gastropods • Provisions for Community production • Imports of live bivalve molluscs from third countries • Live bivalve molluscs may not be prepared for marketing except in establishments meeting the standards	Amendments – Directive • 97/61/EC (entry into force 18/11/1997) • 97/79/EC (entry into force 19/2/1998) ▪ Laying down the organisation of veterinary checks
Directive 91/493/EEC (entry into force 1/1/1993) Laying down the health conditions for the production and the placing on the market of fishery products	• Fishery products which are to be marketed live must at all times be kept under the most suitable survival conditions • Certain species that are poisonous or contain biotoxins may not be marketed • Fishery products may not be handled except in factory ships or establishments conforming to the standards laid down in this Directive	Amendments – Directive • 95/71/EC (entry into force 30/12/1995) • 97/79/EC (entry into force 19/2/1998) ▪ Laying down the organisation of veterinary checks and adding in the Articles
Directive 92/48/EEC (entry into force 1/1/1993) Laying down the minimum hygiene rules applicable to fishery products caught on board certain vessels	• The general hygiene conditions shall apply to fishery products handled on board fishing vessels • The additional hygiene conditions shall apply to fishing vessels designed and equipped to preserve fishery products on board under satisfactory conditions for more than 24 hours	
Decision 97/296/EC (entry into force 1/7/1997) Drawing up the list of third countries from which the import of fishery products is authorised for human consumption	• List of countries and territories from which importation of fishery products in any form intended for human consumption is authorised • Certification that fishery products exported to the Community meet the health requirements	Amendments – Decision • 1999/136/EC (entry into force 8/3/1999) • 1999/244/EC (entry into force 27/4/99) • 1999/277/EC (entry into force 17/5/99) • 1999/488/EC (entry into force 12/8/99) • 1999/532/EC (entry into force 23/8/99) • 1999/814/EC (entry into force 29/12/99) • 2000/88/EC (entry into force 22/2/2000) • 2000/170/EC (entry into force 19/3/00) • 2000/674/EC (entry into force 24/11/00) • 2001/40/EC (entry into force 2/2/2001) • 2001/66/EC (entry into force 13/2/2001) • 2001/111/EC (entry into force 5/3/2001) • 2001/635/EC (entry into force 6/9/2001) • 2002/28/EC (entry into force 4/2/2002)

Table 2.9 (*Continued*)

Title	Main points	Comments
		• 2002/473/EC (entry into force 11/6/02) • 2002/863/EC (entry into force 25/11/02) • 2003/303/EC (entry into force 23/5/03) • 2003/606/EC (entry into force 9/9/2003) • 2003/764/EC (entry into force 14/11/03) • 2004/36/EC (entry into force 3/2/2004) • 2004/359/EC (entry into force 10/4/04) ▪ Addition in the list of countries
Regulation (EC) No. 104/2000 (entry into force 2/2/2000) The common organisation of the markets in fishery and aquaculture products	• A common organisation of markets in fishery products is hereby established, comprising a price and trading system on competition • Marketing standards and consumer information • Conditions for grant of and withdrawal recognition of producer organisations • Production and marketing planning • Trade of fishery products with third countries	Repeals Regulation (EEC) • No. 3759/92 from 1/1/2001 • No. 105/76 from 1/1/2001 • No. 1772/82 from 1/1/2001 • Amendments – Regulation (EC) • No. 2065/2001 (entry into force 1/1/02) • No. 1767/2004 (entry into force 4/11/04) ▪ Corrections in the Articles of this Directive

Adapted from Arvanitoyannis *et al*. (2005).

the withdrawal periods allowed in international recommendations have been observed and (b) meat or products obtained from animals, the importation of which is prohibited.

In agreement with Directive 96/23/EC (entry into force 23/5/1996), substances having an anabolic effect and unauthorised substances are (1) stilbenes, stilbene derivatives and their salts and esters, (2) antithyroid agents, (3) steroids and (4) resorcylic acid lactones including zeranol and beta-agonists. Moreover, veterinary drugs and contaminants which are to be monitored include: (a) antibacterial substances, including sulphonomides, quinolones, (b) other veterinary drugs (anthelmintics, anticoccidials, carbamates and pyrethroids, sedatives, non-steroidal anti-inflammatory drugs, other pharmacologically active substances) and (c) other substances and environmental contaminants (organochlorine compounds including PCBs, organophosphorus compounds, chemical elements, mycotoxins, dyes). The plan used to carry out the required inspections shall (a) provide for detection of groups of residues or substances according to type of animal, (b) specify in particular the measures for detection of the presence of the substances referred in the animals, in the drinking water of the animals and in all places where the animals are bred or kept and residues of the aforementioned substances in live animals, their excrement and body fluids and in animal tissues and products such as meat, milk, eggs and honey and (c) comply with the sampling rules and levels. Member States may have official random checks conducted: (i) during the manufacture of the substances and during their handling, storage, transport, distribution and sale or acquisition, (ii) at any point in the animal foodstuffs production and distribution chain and (iii) throughout the production chain of animals and raw materials of animal origin covered by this Directive. Where illegal treatment is established, the competent authority must ensure that the livestock is immediately placed under official control. Where there is evidence of residues of authorised substances or products of a level exceeding the maximum limit for residues, the competent authority shall carry out an investigation in the farm of origin or departure, as applicable, to determine why the above limit was exceeded. In the event of repeated infringements of maximum residue limits when animals are placed on the market by a farmer or products are placed on the market by a farmer or a processing establishment, intensified checks on the animals and products from the farm and/or establishment in question must be carried out by the competent authorities for a period of at least 6 months, products or carcases being impounded pending the results of analysis of the samples.

Some representative points and comments of the Directives regarding contamination from substances with hormonal action and other substances are given in Table 2.10.

Table 2.10 Directives (main points and comments) for contamination from substances with hormonal action and other substances.

Title	Main points	Comments
Directive 96/22/EC (entry into force 23/5/1996) The prohibition on the use in stockfarming of certain substances having a hormonal or thyrostatic action and of beta-agonists	• The placing on the market and the administering to farm animals of substances having a thyrostatic action or substances having an oestrogenic, androgenic or gestagenic action and of stilbenes and beta-agonists are prohibited • Certain of these substances may be used for therapeutic purposes provided their use is controlled	Repeals • Directive 81/602/EEC from 1/7/1997 • Directive 88/146/EEC from 1/7/1997 • Directive 88/299/EEC from 1/7/1997
Directive 96/23/EC (entry into force 23/5/1996) Measures to monitor certain substances and residues thereof in live animals and animal products	• The to be monitored substances are divided into two groups: substances having anabolic effect and unauthorised substances on the one hand, and veterinary drugs and contaminants on the other. Determination of the official control measures and of those taken in the event of infringement	Repeals • Directive 85/358/EEC from 1/7/1997 • Directive 86/469/EEC from 1/7/1997 • Directive 89/197/EEC from 1/7/1997 • Directive 91/664/EEC from 1/7/1997

Adapted from Arvanitoyannis *et al.* (2005).

2.2.11 Biological safety

Regulation (EC) No. 999/2001 (entry into force 1/7/2001) has no application to (a) cosmetic or medicinal products or medical devices, or to their starting materials or intermediate products, (b) products which are not intended for use in human food, animal feed or fertilisers, or to their starting materials or intermediate products, (c) products of animal origin intended for exhibition, teaching, scientific research, special studies or analysis and (d) live animals used in or intended for research. Each Member State shall carry out an annual programme for monitoring BSE and scrapie. Member States shall inform the Commission of the emergence of a TSE encephalopathy other than BSE. All official investigations and laboratory examinations shall be recorded. Finally, Member States shall submit an annual report to the Commission. According to the Regulation, the following are prohibited: (i) the feeding to any farmed animal of protein derived from mammals, (ii) the feeding to any mammal of processed animal protein derived from mammals and (iii) the feeding to any ruminant of rendered ruminant fat. The following tissues shall be designated as specified risk materials: (a) the skull, including the brain and eyes, the tonsils and the spinal cord of bovine animals aged over 12 months and the intestines of bovine animals of all ages, (b) the skull including the brain and eyes, the tonsils and the spinal cord of ovine and caprine animals aged over 12 months and the spleen of ovine and caprine animals of all ages, (c) the entire head (excluding the tongue) of bovine animals aged over 6 months, and the intestines of animals of all ages, (d) the vertebral column of bovine animals aged over 30 months and (e) the skull including the brain and eyes, the tonsils, the spinal cord of ovine and caprine animals aged over 12 months and the spleen of ovine and caprine animals of all ages. All these shall be removed from slaughterhouses, cutting plants, high-risk processing plants or premises. Any animal suspected of being infected by a TSE shall be placed under an official movement restriction until the results of a clinical and epidemiological examination are known. Where the competent authority decides that the possibility of infection with a TSE cannot be ruled out, the animal shall be killed, if it is still alive; its brain and all other tissues as the competent authority may determine shall be removed and sent to an officially approved laboratory. When the presence of a TSE has been officially confirmed, the following measures shall be applied as soon as possible: (1) all parts of the body of the animal shall be completely destroyed, (2) an enquiry shall be carried out to identify all animals at risk and (3) all animals and products of animal origin that have been identified as being at risk, shall be killed and completely destroyed. The use of ruminant materials for the production of the following products of animal origin is prohibited: mechanically recovered meat, dicalcium phosphate intended as foodstuffs for livestock, gelatin, unless it is produced from ruminant

Table 2.11 Regulations (main points and comments) with regard to biological safety.

Title	Main points
Regulation (EC) No. 999/2001 (entry into force 1/7/2001) Rules for the prevention, control and eradication of certain transmissible spongiform encephalopathies (TSEs)	• Rules for the prevention, control and eradication of TSEs in animals • Application to the production and placing on the market of live animals and products of animal origin and in certain specific cases to exports thereof • Member States shall carry out an annual programme for monitoring BSE and scrapie • The feeding to ruminants of protein derived from mammals is prohibited • The specified risk material shall be removed and destroyed
Regulation (EC) No. 2160/2003 (entry into force 12/12/2003) The control of *Salmonella* and other specified foodborne zoonotic agents	• Measures to detect and to control *Salmonella* and other zoonotic agents • Application to production, processing and distribution • Designation of a competent authority for each Member State and arrangement of responsibilities • Arrangement of control plans • Imports from third countries only if specific conditions are met

Adapted from Arvanitoyannis *et al*. (2005).

hides, derivatives made from rendered ruminant fat and rendered ruminant fat.

The purpose of Regulation (EC) No. 2160/2003 (entry into force 12/12/2003) is to ensure that proper and effective measures are taken to detect and to control salmonella and other zoonotic agents at all relevant stages of production, processing and distribution, particularly at the level of primary production, including in feed, in order to reduce their prevalence and the risk they pose to public health. This Regulation shall cover: (a) the adoption of targets for the reduction of the prevalence of specified zoonoses in animal populations, (b) the approval of specific control programmes established by Member States and food and feed business operators, (c) the adoption of specific rules concerning certain control methods applied in the reduction of the prevalence of zoonoses and zoonotic agents and (d) the adoption of rules concerning intra-Community trade and imports from third countries of certain animals and products thereof. It shall not apply to primary production: (a) for private domestic use or (b) leading to the direct supply, by the producer, of small quantities of primary products to the final consumer or to local retail establishments directly supplying the primary products to the final consumer. Each Member State shall designate a competent authority or competent authorities for the purpose of this Regulation and notify the Commission thereof. The Community targets for the reduction of the prevalence of zoonoses and zoonotic agents consist at least of a numerical expression of (a) the maximum percentage of epidemiological units remaining positive and/or the minimum percentage of reduction in the number of epidemiological units remaining positive, (b) the maximum time limit within which the target must be achieved, (c) the definition of the epidemiological units, (d) the definition of the testing schemes necessary to verify the achievement of the target and (e) the definition, where relevant, of serotypes with public health significance or of other subtypes of zoonoses or zoonotic agents. To achieve the Community targets, Member States shall establish national control programmes for each zoonosis and zoonotic agent. National control programmes shall cover at least the following stages of the food chain: feed production, primary production of animals, processing and preparation of food of animal origin. After a Member State submits a national control programme, the Commission shall have 2 months within which to request any further relevant and necessary information from that Member State. The Member State shall provide such further information within 2 months of receiving such a request. The Commission shall, within 2 months of receiving such further information or, if it did not request further information, within 6 months of the submission of the control programme, establish whether it complies with relevant rules, including this Regulation in particular.

Some points of the EU legislation focused on biological safety are stated in Table 2.11.

2.3 US LEGISLATION FOR FOOD OF ANIMAL ORIGIN

2.3.1 Meat, poultry and their products legislation

Following the Federal Meat Inspection Act (1908), 'meat food product' means any product capable of use as human food which is made wholly or in part from any meat or other portion of the carcass of any cattle, sheep, swine or goats, excepting products which contain meat or other portions of such carcasses only in

a relatively small proportion or historically have not been considered by consumers as products of the meat food industry, and which are exempted from definition as a meat food product by the Secretary under such conditions as he or she may prescribe to assure that the meat or other portions of such carcasses contained in such product are not adulterated and that such products are not represented as meat food products. This term as applied to food products of equines shall have a meaning comparable to that provided in this paragraph with respect to cattle, sheep, swine and goats. For the purpose of preventing the use in commerce of meat and meat food products which are adulterated, the Secretary shall cause to be made, by inspectors appointed for that purpose, an examination and inspection of all cattle, sheep, swine, goats, horses, mules and other equines before they shall be allowed to enter into any slaughtering, packing, meat-canning, rendering or similar establishment, in which they are to be slaughtered and the meat and meat food products thereof are to be used in commerce; and all cattle, sheep, swine, goats, horses, mules and other equines found on such inspection to show symptoms of disease shall be set apart and slaughtered separately from all other cattle, sheep, swine, goats, horses, mules or other equines, and when so slaughtered the carcasses of said cattle, sheep, swine, goats, horses, mules or other equines shall be subject to a careful examination and inspection, all as provided by the rules and regulations to be prescribed by the Secretary.

In the Poultry Products Inspection Act (1968), 'poultry' means any domesticated bird, whether live or dead and 'poultry product' means any poultry carcass, or part thereof; or any product which is made wholly or in part from any poultry carcass or part thereof, excepting products which contain poultry ingredients only in a relatively small proportion or historically have not been considered by consumers as products of the poultry food industry, and which are exempted by the Secretary from definition as a poultry product under such conditions as the Secretary may prescribe to assure that the poultry ingredients in such products are not adulterated and that such products are not represented as poultry products. Each official establishment slaughtering poultry or processing poultry products for commerce or otherwise subject to inspection under this chapter shall have such premises, facilities and equipment, and be operated in accordance with such sanitary practices, as are required by regulations promulgated by the Secretary for the purpose of preventing the entry into or flow or movement in commerce or burdensome effect upon commerce, of poultry products which are adulterated. No slaughtered poultry, or parts or products thereof, of any kind shall be imported into the United States unless they are healthful, wholesome, fit for human food, not adulterated, and contain no dye, chemical, preservative or ingredient which renders them unhealthful, unwholesome, adulterated or unfit for human food and unless they also comply with the rules and regulations made by the Secretary of Agriculture to assure that imported poultry or poultry products comply with the standards provided for in this chapter.

For the purpose of Egg Products Inspection (1970), 'egg product' means any dried, frozen or liquid eggs, with or without added ingredients, excepting products which contain eggs only in a relatively small proportion or historically have not been, in the judgement of the Secretary, considered by consumers as products of the egg food industry, and which may be exempted by the Secretary under such conditions as he or she may prescribe to assure that the egg ingredients are not adulterated and such products are not represented as egg products and 'egg' means the shell egg of the domesticated chicken, turkey, duck, goose or guinea. Eggs and egg products found to be adulterated at official plants shall be condemned and, if no appeal be taken from such determination of condemnation, such articles shall be destroyed for human food purposes under the supervision of an inspector: Provided that articles which may by reprocessing be made not adulterated need not be condemned and destroyed if so reprocessed under the supervision of an inspector and thereafter found to be not adulterated. If an appeal be taken from such determination, the eggs or egg products shall be appropriately marked and segregated pending completion of an appeal inspection, which appeal shall be at the cost of the appellant if the Secretary determines that the appeal is frivolous. If the determination of condemnation is sustained, the eggs or egg products shall be destroyed for human food purposes under the supervision of an inspector.

Following meat and poultry pathogen reduction and Hazard Analysis and Critical Control Point (HACCP) systems (1996), each official establishment that slaughters cattle and/or hogs shall test for *E. coli* Biotype I (*E. coli*) and shall (i) collect samples in accordance with the sampling techniques and methodology and (ii) obtain analytic results. An establishment's raw meat products or raw poultry products, when sampled and tested by Food Safety and Inspection Service (FSIS) for *Salmonella*, may not test positive for *Salmonella* at a rate exceeding the applicable national pathogen reduction performance standard. Food safety hazards might be expected to arise from the following: (i) natural toxins, (ii) microbiological contamination, (iii) chemical contamination, (iv) pesticides, (v) drug residues, (vi) zoonotic diseases, (vii) decomposition,

(viii) parasites, (ix) unapproved use of direct or indirect food or colour additives and (x) physical hazards. Every establishment shall develop and implement whenever a hazard analysis reveals one or more food safety hazards that are reasonably likely to occur including products in the following processing categories: (a) slaughter – all species, (b) raw product – ground, (c) raw product – not ground, (d) thermally processed – commercially sterile, (e) not heat treated – shelf stable, (f) heat treated – shelf stable, (g) fully cooked – not shelf stable, (h) heat treated but not fully cooked – not shelf stable and (i) product with secondary inhibitors – not shelf stable.

Meat, Poultry and Egg Products Inspection (1999): (i) requires that each plant develop and implement written standard operating procedures for sanitation to reduce the likelihood that harmful bacteria will contaminate the finished product, (ii) requires regular microbial testing by slaughter establishments to verify the adequacy of their process controls for preventing and removing faecal contamination, (iii) established pathogen reduction performance standards for *Salmonella* that slaughter plants and plants producing raw ground products had to meet and (iv) required that all meat and poultry plants develop and implement HACCP systems to prevent food safety problems, by addressing microbial, chemical and physical hazards reasonably likely to occur. FSIS began conducting a risk assessment for *E. coli* O157:H7 in ground beef and carcass trimmings. The risk assessment will estimate the risk of foodborne illness from *E. coli* O157:H7 both with existing programmes and practices and with alternative mitigation strategies. FSIS is exploring whether further changes are needed in its policy regarding *E. coli* O157:H7 in the light of new information that is emerging about the pathogen and its relation to human health. FSIS will re-evaluate its policy on *E. coli* O157:H7 through an open, participatory process, soliciting input from all of its various constituents.

In the Meat and Poultry Inspection Issues (2000), no meat or poultry establishment can slaughter or process products for human consumption until FSIS approves in advance its plans and specifications for the premises, equipment and operating procedures. A key feature of the programme is that FSIS must inspect all meat and poultry animals at slaughter on a continuous basis; that is, no animal may be slaughtered and dressed unless an inspector has examined each carcass. One or more federal inspectors are 'on the line' during all hours the plant is operating; the appropriate number depends upon each plant's production level. Since the programme's inception, inspectors have relied mostly on *organoleptic* detection procedures: sight, touch and smell. They conduct both ante-mortem (before slaughter) and post-mortem (after slaughter) inspection. Inspectors look for signs of disease, contamination and/or other abnormal conditions. FSIS's legal inspection responsibilities do not begin until animals arrive at slaughterhouses, and they generally end once products leave processing plants. The agency has no regulatory jurisdiction at the farm level. The US Department of Agriculture (USDA) states that generic *E. coli* was chosen because it is the best microbial indicator of faecal contamination, the primary vehicle for such potentially dangerous bacteria as *Salmonella*, *Campylobacter* and *E. coli* O157:H7. USDA inspectors conduct the *Salmonella* testing. Plants were required to begin meeting the standards when they implemented their HACCP plans.

US legislation dealing with meat, poultry and their products are given in Table 2.12.

2.3.2 US legislation for fish and fishery products

According to procedures for the safe and sanitary processing and importing of fish and fishery products (1995), 'fish' means fresh or saltwater finfish, crustaceans, other forms of aquatic animal life (including, but not limited to, alligator, frog, aquatic turtle, jellyfish, sea cucumbers, and sea urchin and the roe of such animals) other than birds or mammals, and all molluscs, where such animal life is intended for human consumption; 'fishery products' mean any human food product in which fish is a characterising ingredient. The HACCP plan shall at a minimum list the food safety hazards that are reasonably likely to occur and that thus must be controlled for each fish and fishery product. Food safety hazards are reasonably likely to occur as a result of the following: (i) natural toxins, (ii) microbiological contamination, (iii) chemical contamination, (iv) pesticides, (v) drug residues, (vi) decomposition in scombroid toxin, (vii) parasites, (viii) unapproved use of direct or indirect food or colour additives and (ix) physical hazards. Every importer of fish and fishery products shall either obtain the fish or fishery product from a country that has an active memorandum of understanding (MOU) or similar agreement that covers the fish or fishery product and documents the equivalency or compliance of the inspection system of the foreign country with the US system or have and implement written verification procedures for ensuring that the fish and fishery products that they offer for import into the United States were processed in accordance with the requirements of this part. Processors of smoked or smoke-flavoured fishery products shall include in their HACCP plans how they are controlling the food safety hazard associated with the formation

Table 2.12 US legislation related to meat, poultry and their products.

Title	Entry into force	Main points	Comments
Federal Meat Inspection Act	1908	• Definitions (meat food product etc.) • Inspection of meat and meat food products • Sanitary inspection and regulation of slaughtering and packing establishments; rejection of adulterated meat or meat food products • Marking, labelling or other identification of kinds of animals of articles' derivation; separate establishments for preparation and slaughtering activities	Amendments • 1958 (changes in slaughtering and handling methods) • 1967 (amendments in the slaughter, storage, handling and distribution of carcases) • 1970 (repeal two sections of the Act) • 1999 (replacements of sections)
Poultry Products Inspection Act	1968	• Poultry and poultry products are an important source of the nation's total supply of food • Definitions (poultry, poultry products etc.) • Federal and State cooperation in development and administration of State poultry product inspection programmes • Sanitary practices • Storage and handling of poultry products	
Egg Products Inspection	1970	• Eggs and egg products are an important source of the nation's total supply of food, and are used in food in various forms • Definitions (egg product, egg etc.) • Inspection of egg products • Pasteurisation and labelling of egg products at official plants	
Meat and poultry pathogen reduction and Hazard Analysis and Critical Control Point (HACCP) systems	1996	• Contamination with micro-organisms, pathogen reduction performance standards for *Salmonella* • Poultry products inspection regulations • Sanitation control procedures for meat and poultry	
Meat, Poultry and Egg Products Inspection	1999	• The Food Safety and Inspection Service (FSIS), a public health regulatory agency within the US Department of Agriculture (USDA), is responsible for ensuring that the commercial supply of meat, poultry and egg products in the United States is safe, wholesome and accurately labelled • FSIS and FDA worked together on a *Listeria monocytogenes* (*Listeria*) risk ranking	
Meat and Poultry Inspection Issues	2000	• The USDA's FSIS is responsible for inspecting most meat, poultry and processed egg products for safety, wholesomeness and proper labelling • No meat or poultry establishment can slaughter or process products for human consumption until FSIS approves in advance its plans and specifications for the premises, equipment and operating procedures • FSIS's legal inspection responsibilities do not begin until animals arrive at slaughterhouses, and they generally end once products leave processing plants	

Adapted from Arvanitoyannis *et al*. (2006).

Table 2.13 US legislation for fish and fishery products.

Title		Main points
Procedures for the safe and sanitary processing and importing of fish and fishery products	1995	• Definitions (fish, fishery products etc.) • Current good manufacturing practice • Special requirements for imported products and for processing smoked, smoke-flavoured fishery products, fresh and frozen molluscan shellfish
Sustainable Fishery Act	1996	• Fishery monitoring, research and management plans • Fisheries financing and capacity reduction

Adapted from Arvanitoyannis *et al.* (2006).

of toxin by *Clostridium botulinum* for at least as long as the shelf life of the product under normal and moderate abuse conditions.

For the purpose of Sustainable Fishery Act (1996), 'commercial fishing' means fishing in which the fish harvested, either in whole or in part, are intended to enter commerce or enter commerce through sale, barter or trade and 'fishing community' means a community which is substantially dependent on or substantially engaged in the harvest or processing of fishery resources to meet social and economic needs, and includes fishing vessel owners, operators and crew and the US fish processors that are based in such community. The North Pacific Council and the Secretary shall establish a western Alaska community development quota programme under which a percentage of the total allowable catch of any Bering Sea fishery is allocated to the programme. To be eligible to participate in the western Alaska community development quota programme under subparagraph, a community shall (i) be located within 50 nautical miles from the baseline from which the breadth of the territorial sea is measured along the Bering Sea coast from the Bering Strait to the westernmost of the Aleutian Islands, or on an island within the Bering Sea, (ii) not be located on the Gulf of Alaska coast of the North Pacific Ocean, (iii) meet criteria developed by the Governor of Alaska, approved by the Secretary, and published in the Federal Register, (iv) be certified by the Secretary of the Interior pursuant to the Alaska Native Claims Settlement Act to be a Native village, (v) consist of residents who conduct more than one-half of their current commercial or subsistence fishing effort in the waters of the Bering Sea or waters surrounding the Aleutian Islands and (vi) not have previously developed harvesting or processing capability sufficient to support substantial participation in the groundfish fisheries in the Bering Sea, unless the community can show that the benefits from an approved Community Development Plan would be the only way for the community to realise a return from previous investments. The recommendations shall be developed after consultation with interested governmental and non-governmental parties and shall (1) be designed to standardise the requirements of vessel registration and information collection systems required by this Act, the Marine Mammal Protection Act and any other marine resource law implemented by the Secretary, and, with the permission of a State, any marine resource law implemented by such State, (2) integrate information collection programmes under existing fishery management plans into a non-duplicative information collection and management system, (3) avoid duplication of existing State, tribal or Federal systems and shall utilise, to the maximum extent practicable, information collected from existing systems, (4) provide for implementation of the system through cooperative agreements with appropriate State, regional or tribal entities and Marine Fisheries Commissions, (5) provide for funding (subject to appropriations) to assist appropriate State, regional or tribal entities and Marine Fisheries Commissions in implementation, (6) establish standardised units of measurement, nomenclature and formats for the collection and submission of information, (7) minimise the paperwork required for vessels registered under the system, (8) include all species of fish within the geographic areas of authority of the Councils and all fishing vessels including charter fishing vessels, but excluding recreational fishing vessels and (9) require the US fish processors, and fish dealers and other first ex-vessel purchasers of fish that are subject to the proposed system, to submit information (other than economic information) which may be necessary to meet the goals of the proposed system.

A summary of the US legislation focused on fish and fishery products is given in Table 2.13.

2.4 CANADIAN LEGISLATION FOR FOOD OF ANIMAL ORIGIN

2.4.1 Meat legislation

According to Meat Inspection Act (1985), it shall be a condition of the registration and operation of an

establishment as a registered establishment that the establishment and all animals and meat products in it are subject to this Act and the regulations. No person shall operate a registered establishment unless that person has obtained a licence therefore in accordance with the regulations. The meat inspection legend shall be a national trademark, and the exclusive property in and, subject to this Act, the right to the use of that trademark is hereby declared to be vested in Her Majesty in right of Canada. No person shall export a meat product out of Canada unless (a) it was prepared or stored in a registered establishment that was operated in accordance with this Act and the regulations, (b) that person provides an inspector with evidence satisfactory to the Minister that the meat product meets the requirements of the country to which it is being exported and (c) that person obtains a certificate from an inspector authorising the export of that meat product. No person shall import a meat product into Canada unless (a) at the time it was prepared for export, the country from which it originated and any country in which it was processed had meat inspection systems, those systems and the relevant establishments in those countries were approved in writing by the Minister before that time and the approvals were valid at that time, (b) that person provides an inspector with evidence satisfactory to the Minister that it meets the prescribed standards for imported meat products, (c) it meets the prescribed standards for imported meat products and (d) it is packaged and labelled in the manner prescribed. The Governor in Council may make regulations for carrying out the purposes and provisions of this Act and, without limiting the generality of the foregoing, may make regulations (a) prescribing the meat inspection legend and the form and manner in which, terms and conditions on which, persons by whom and things in connection with which it may be applied or used, (b) governing the registration of establishments and the licensing of the operators thereof, and prescribing the fees payable therefore, (c) providing for the cancellation and suspension of the registration of registered establishments, (d) governing the design, construction and maintenance of registered establishments and of the equipment and facilities therein, (e) respecting the operation and suspension of operation of registered establishments, (f) prescribing the equipment and facilities to be used, the procedures to be followed and the standards to be maintained in registered establishments to ensure humane treatment and slaughter of animals and hygienic processing and handling of meat products, (g) providing for the inspection of establishments and registered establishments and the animals and meat products in registered establishments and prescribing the fees payable therefore, (h) providing for the reinspection of meat products in connection with which the meat inspection legend is applied or used and prescribing the fees payable therefore, (i) prescribing standards for meat products that are prepared or stored in registered establishments, for meat products that enter into interprovincial or international trade and for meat products in connection with which the meat inspection legend is applied or used, (j) prescribing standards for imported meat products, (k) governing the packaging and labelling of meat products and prescribing the specifications for the packages and labels, (l) respecting the withholding from slaughter of animals and the inspection, holding, treatment, condemnation, confiscation and disposal of animals, meat products or other things in registered establishments that are or are suspected on reasonable grounds of being injurious to health or otherwise in contravention of this Act or the regulations, (m) respecting the inspection and disposal of imported meat products and prescribing the fees payable for such inspection, (n) providing for systems for ascertaining the places of origin of the animals to be slaughtered in registered establishments, (o) prescribing the manner of seizing and detaining anything under this Act and providing for the safe-keeping and disposal of anything seized, detained or forfeited under this Act, (p) respecting the storage, handling and transportation of meat products and the payment of expenses in connection with that storage, (q) prohibiting the transportation of meat products unless they are properly packaged and labelled under this Act and the regulations and evidence satisfactory to the Minister are provided that they meet any other requirements of this Act and the regulations, (r) exempting any person, establishment, registered establishment, animal, meat product or any class thereof from the application of this Act or the regulations or any provisions thereof, subject to such terms and conditions as the Governor in Council considers appropriate and (s) prescribing anything that by this Act is to be prescribed. The main points of this Act are given in Table 2.14.

2.4.2 Fish and fishery products legislation

The Fish Inspection Act (1985) applies to the shipment of fish or marine plants from one province to another as though the shipment from a province were an export and the shipment into a province were an import. The Governor in Council may, for the purpose of regulating the export or import of fish and containers, make regulations (a) prescribing grades, quality and standards of fish; (b) defining, for the purposes of section 10, the expressions 'tainted', 'decomposed' and 'unwholesome'; (c) respecting the processing, storing, grading, packaging, marking, transporting and inspection of fish; (d) respecting the quality and specifications for

Table 2.14 Canadian legislation focused on meat.

Title	Year	Main points
Meat Inspection Act	1985	• Provisions for export, interprovincial trade and import • The Governor in Council may make regulations for carrying out the purpose of this Act • It shall be a condition of the registration and operation of an establishment as a registered establishment that the establishment and all animals and meat products in it are subject to this Act and the regulations

containers and the marking and inspection of containers; (e) requiring the registration of establishments and the licensing of persons engaged as principals or agents in the export or import of fish or containers; (f) prescribing the requirements for the equipment and sanitary operation of establishments, of premises operated by an importer for the purpose of importing fish, and of any boats, vehicles or other equipment used in connection with an establishment or in connection with fishing or the import or export of fish; (g) prescribing fees for registration of establishments, issue of licences and grading and inspection services; (h) prohibiting the sale or offering for sale or holding in possession for sale of any fish or containers under any grade name or standard prescribed by regulations made under this Part unless all the requirements of this Part and the regulations thereunder with respect thereto have been complied with, or under any name calculated to mislead or deceive; (i) prescribing the manner in which samples of any fish may be taken; (j) prohibiting or restricting any export or import of, or any attempt or offer to export or import, any fish or containers unless all the requirements of this Part and the regulations thereunder with respect thereto have been complied with and (k) establishing requirements governing the seizure and detention of fish and containers. A thing seized under this Act, or the proceeds realised from its disposition, shall not be detained after (a) an inspector determines that this Act and the regulations have been complied with in relation to the thing, or (b) the expiration of 180 days after the day of its seizure, or such longer period as may be prescribed, unless before that time proceedings are instituted in relation to the thing seized, in which case it may be detained until the proceedings are finally concluded. The Governor in Council may make regulations (a) prescribing standards of grade, class or quality for marine plants and the names or marks that may be used to designate any such grade, class or quality; (b) providing for inspection, grading and labelling of marine plants, the form, issue and use of inspection certificates, and prescribing inspection fees; and (c) generally for carrying any of the purposes or provisions of this Part into effect. Every person who contravenes a provision of this Act or a regulation made under it is guilty of an offence and liable (a) on summary conviction (i) to a fine not exceeding $20,000 or to imprisonment for a term not exceeding 3 months or to both, or (ii) for a subsequent offence, to a fine not exceeding $50,000 or to imprisonment for a term not exceeding 2 years or to both; or (b) on conviction by indictment (i) in the case of a corporation, to a fine not exceeding $250,000, and (ii) in the case of an individual, to a fine not exceeding $100,000 or to imprisonment for a term not exceeding 5 years or to both.

In agreement with Fresh Fish Marketing Act (1985), the Corporation is established for the purpose of marketing and trading in fish, fish products and fish by-products in and outside Canada and, in addition to the powers conferred by other provisions of this Act and by any other Act, has for that purpose power to (a) buy fish and dress, fillet, freeze, package or otherwise prepare fish for market; (b) buy, manufacture or produce fish products and fish by-products and package or otherwise prepare fish products and fish by-products for market; (c) store, ship, insure, import, export, market, sell or otherwise dispose of fish, fish products and fish by-products bought, prepared, manufactured or produced by it; (d) purchase, lease or otherwise acquire and hold, sell or otherwise deal with any real property; (e) establish branches or employ agents in Canada or elsewhere; (f) invest any money in its possession or under its control that in its opinion is not immediately required for the purposes of its operations, in securities of or guaranteed by the Government of Canada and sell any securities so acquired by it and reinvest the proceeds or any part of the proceeds thereof in like manner; (g) borrow money from any bank on the credit of the Corporation; (h) make loans of working capital on a seasonal basis to persons engaged in fishing for commercial purposes in a participating province; and (i) do all such other things as are necessary or incidental to the exercise of any of its powers or the carrying out of any of its functions under this Act. For the purpose of enabling the Corporation to carry on its operations under this Act, the Governor in Council

Table 2.15 Canadian legislation for fish and fishery products.

Title	Year	Main points
Fish Inspection Act	1985	• Regulating the export or import of fish and containers • Regulating marine plants • This Act applies to the shipment of fish or marine plants
Fresh Fish Marketing Act	1985	• Export trade in fish • Marketing and trading in fish, fish products and fish by-products

may authorise the Minister of Finance, on such terms and conditions as may be agreed on (a) to guarantee repayment of loans, and interest thereon, made by any bank to the Corporation; and (b) to make loans to the Corporation. Except in accordance with the terms and conditions set out in any licence that may be issued by the Corporation in that behalf, no person, other than the Corporation or an agent of the Corporation, shall (a) export fish from Canada; (b) send, convey or carry fish from a participating province to another participating province or to any other province; (c) in a participating province, receive fish for conveyance or carriage to a destination outside the province; or (d) sell or buy, or agree to sell or buy, fish situated in a participating province for delivery in another participating province or any other province, or outside Canada.

Some representative points and comments of the Acts regarding fish and fishery products are given in Table 2.15.

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EU legislation

Directives on controls and food hygiene rules

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http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=85&nu_doc=591

93/43/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=93&nu_doc=43

93/99/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=93&nu_doc=99

2002/99/EC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=2002&nu_doc=99

2004/41/EC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=2004&nu_doc=41

Directives related to imports from third countries and intra-Community trade; general provisions

89/662/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=89&nu_doc=662

90/425/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=90&nu_doc=425

91/174/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=91&nu_doc=174

91/496/EEC
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92/65/EEC
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97/78/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=97&nu_doc=78

Directives related to production and placing on the market – milk

89/384/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=89&nu_doc=384
92/46/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=92&nu_doc=46

Directives for production and placing on the market – meat

91/495/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=91&nu_doc=495
92/45/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=92&nu_doc=45
94/65/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=94&nu_doc=65

Directives dealing with specific provisions – bovine and porcine animals

64/432/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=64&nu_doc=432
72/462/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=72&nu_doc=462
77/96/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=77&nu_doc=96
77/504/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=77&nu_doc=504
88/407/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=88&nu_doc=407
88/661/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=88&nu_doc=661
89/556/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=89&nu_doc=556
90/429/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=90&nu_doc=429
Decision 1999/879/EC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Decision&an_doc=1999&nu_doc=879

Directives related to specific provision – ovine and caprine animals

72/462/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=72&nu_doc=462
89/361/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=89&nu_doc=361
91/68/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=91&nu_doc=68
2004/68/EC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=2004&nu_doc=68

Directives with regard to specific provisions – poultry

71/118/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=71&nu_doc=118
89/437/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=89&nu_doc=437
90/539/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=90&nu_doc=539
92/116/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=92&nu_doc=116

Directives for specific provisions – meat and meat-based production

72/461/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=72&nu_doc=461

80/215/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=80&nu_doc=215
91/497/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=91&nu_doc=497
96/22/EC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=96&nu_doc=22

Directives focused on specific provisions – fish and fishery products

91/67/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=91&nu_doc=67
91/492/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=91&nu_doc=492
91/493/EEC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=91&nu_doc=493
92/48/EEC
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http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Regulation&an_doc=2000&nu_doc=104

Directives for contamination from substances with hormonal action and other substances

96/22/EC
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&1g=en&type_doc=Directive&an_doc=96&nu_doc=22
96/23/EC
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Regulations with regard to biological safety

Regulation (EC) No. 999/2001
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Poultry Products Inspection Act
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Meat, Poultry and Egg Products Inspection
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Procedures for the safe and sanitary processing and importing of fish and fishery products
http://www.cfsan.fda.gov/~lrd/searule3.html
Sustainable Fishery Act
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Canadian legislation

Meat Inspection Act
http://lois.justice.gc.ca/en/showdoc/cs/M-3.2//20070313/en?command=home&caller=SI&fragment=meat&search_type=all&day=13&month=3&year=2007&search_domain=cs&showall=L&statuteyear=all&lengthannual=50&length=50
Fish Inspection Act
http://lois.justice.gc.ca/en/showdoc/cs/F-13//20070314/en?command=home&caller=SI&fragment=Fish&search_type=all&day=14&month=3&year=2007&search_domain=cs&showall=L&statuteyear=all&lengthannual=50&length=50
Freshwater Fish Marketing Act
http://laws.justice.gc.ca/en/F-13/index.html

Electronic references

http://www.fst.vt.edu/undergraduate. courses.html
http://europa.eu.int/comm/food/animal products/milk/index_en.htm
http://www.washingtonwatchdog.org/documents/usc/index.html
http://www.onderzoekinformatie.nl/en/oi/nod/onderzoek/OND1305164/

Part II
Implementing HACCP and ISO 22000 for Foods of Animal Origin

HACCP and ISO 220: Application to Foods of Animal Origin
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3
Dairy Foods

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3.1 PRODUCTION OF RAW AND PASTEURISED MILK – POTENTIAL HAZARDS

Pasteurised milk is the largest selling milk in most industrialised countries because the consumption of raw milk carries the risk of infection by milk-borne pathogens, especially *Salmonella* (Small and Sharp, 1979), *Campylobacter* (Heeschen, 1996; Potter *et al*., 1983; Summer, 1996) and tuberculosis (Pinto Angela *et al*., 2006). The International Dairy Federation has defined pasteurisation as, 'A process applied to a product with the object of minimising possible health hazards arising from pathogenic micro-organisms associated with milk, by heat treatment, which is consistent with minimal chemical, physical and sensory changes in the product' (EEC 92/46, 1992; EEC 93/43, 1993; Mossel, 1981; Varnam and Sutherland, 1996). However, in some countries, farms are still allowed to sell raw milk for household use. In the UK and several other countries, bottled raw milk can be directly delivered to customers provided that milk-producing cows have been attested free from tuberculosis and brucellosis (Mossel *et al*., 1995).

Bovine milk-derived ingredients (non-fat dried milk [NFDM], milk protein concentrate [MPC] and whey protein concentrate [WPC]) from cows hyperimmunised with a variety of antigens have been available experimentally or commercially for several decades. Although the safety of milk is rarely questioned, an assessment of ingredients derived from the milk of cows hyperimmunised with a proprietary bacterin (S100) consisting of heat killed cultures of 26 bacterial pathogens, originally isolated from humans, obtained from the American Type Culture Collection, was made to determine that these ingredients share the human food safety profile traditionally ascribed to regular milk (Gingerich and McPhillips, 2005). The critical elements in this determination are: (1) quantitative determination of the difference between S100 and regular dairy ingredients, (2) comparison of exposures resulting from proposed uses to background exposures already in the American diet and (3) corroborative results of controlled clinical trials comparing safety outcomes from consumption of S100 with those of conventional dairy ingredients. Comparative analytical data reveal that the only difference between S100 and conventional dairy ingredients is significantly higher active (undenatured) immunoglobulin G (IgG) (61–79% versus control grade A fluid and powdered skim, respectively, $p < 0.005$) with slightly altered specific antibody activity. Estimated daily intake projections showed that use of S100 ingredients at maximum proposed levels resulted in exposures to active (undenatured) IgG below background in the present American diet in infants but above background in children and adults, whose intake of conventional dairy products is markedly lower. Safety of this consumption level is corroborated by clinical results showing no difference in safety outcomes between S100 ingredients, consumed at exaggerated levels, and conventional dairy products, in a variety of adult populations. There is no evidence that demonstrates a hazard to the public when S100 ingredients are used at levels that might reasonably be expected from the proposed applications.

Raw milk is an excellent medium for the growth of micro-organisms which can be derived from the udder, the environment, milk handling equipment and personnel (Mossel *et al*., 1995). *Escherichia coli*, *Staphylococcus aureus*, *Corynebacterium bovis*, *Streptococcus agalactiae*, *Str. dysgalactiae* and *Str. uberis* (Hahn, 1996) may cause under certain circumstances mastitis, leading to significant economic losses (Barkema *et al*., 1998; Elbers *et al*., 1998). In winter months, feed and bedding are the main sources of thermoduric spoilage

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organisms, while milk handling equipment is the major source of Gram-negative, psychotropic spoilage bacteria. Employees suffering from clinical symptoms of infection, and faeces may contaminate milk with *Campylobacter* and *Salmonella*.

Milk should only be accepted at the dairy plant when obtained from animals which are not suffering from tuberculosis and brucellosis (Romero *et al*., 1995); are free from contagious diseases (Heeschen, 1996; Troutt *et al*., 1995); are not suffering from clinical mastitis (Mossel *et al*., 1995); have not been treated with antibiotics unless milk has been obtained after expiration of the retention period following veterinary treatment (Troutt *et al*., 1995); are subjected to proper supervision and support from relevant authorities (Tschumi, 1997); and do not suffer from infections or tissue damage of the udder (Burgess *et al*., 1994).

The use of antimicrobial drugs in livestock is suspected to contribute to bacterial antimicrobial resistance (AR) development. Dairy farms experiencing recent outbreaks of salmonellosis involving multiresistant (MR) *Salmonella* strains were compared to control farms with respect to AR among bovine commensal *E. coli* isolates (DeFrancesco *et al*., 2004). For most antimicrobials tested, the percentage of AR *E. coli* isolated from salmonellosis-affected farms was significantly higher than that from control farms. Calf *E. coli* from both case and control farms had greater levels of AR than cow isolate. Commensal *E. coli* isolates from case farms and calves tended to more frequently be MR. These data are consistent with the existence of higher antimicrobial selection pressure on farms with recent salmonellosis outbreaks; however, the directionality of the relationship remains to be elucidated.

Pathogens that have been involved in foodborne outbreaks associated with the consumption of milk include *Listeria monocytogenes*, *Salmonella*, *Campylobacter*, *S. aureus*, *B. cereus and Clostridium botulinum*. Most recently, *E. coli* O157:H7 has become a serious threat to the dairy industry with several outbreaks reported in developed countries ranging from mild diarrhoea to potentially fatal haemolytic uraemic syndrome (HUS), haemorrhagic colitis and thrombotic thrombocytopenic purpura (Coia *et al*., 2001).

Levels of listeriosis in the human population have always been greatly overshadowed by other foodborne illnesses, such as salmonellosis or campylobacteriosis, and substantiated foodborne outbreaks of listeriosis were rare. Outbreaks of foodborne listeriosis in the early 1980s, however, demonstrated the severe nature of the illness with exceptionally high levels of mortality, particularly in the most vulnerable members of the community such as unborn babies, the elderly and the immunocompromised (Bell and Kyriakides, 2005).

Listeria monocytogenes is a widely occurring environmental contaminant whose primary means of transmission to humans is through contamination of foodstuffs at any point in the food chain, from source to kitchen. The total elimination of *Listeria monocytogenes* from all food is impractical and may be impossible. This claim comes from the 'Conclusion and Recommendations' in the report of a World Health Organization informal working group convened in 1988 to discuss foodborne listeriosis. *Listeria monocytogenes* is widespread in nature and can be found in raw fish, shellfish, meat, milk, poultry, vegetables etc. (Codex Alimentarius Commission, 1996). *Listeria* species are Gram-positive, short, non-sporing rods that are motile at 20–25°C by means of new peritrichous flagella that give a tumbling form of motility (Farber and Peterkin, 2000). Some examples of the process stages where *Listeria monocytogenes* may represent a hazard in dairy products are given in Table 3.1.

From the 930 milk samples tested in Malaysia by Chye *et al*. (2004), approximately 90% were contaminated by coliform bacteria and 65% were *E. coli* positive, with mean counts ranging from 10^3 to 10^4 colony forming unit (cfu)/mL. *S. aureus* was isolated from more than 60% of the samples and the mean count per millilitre was 12×10^3. Meanwhile, *E. coli* O157:H7 was also detected in 312 (33.5%) samples. However, *Salmonella* was only detected in 1.4% of the samples, with the Central region having the highest frequency of isolation. Thirteen *Salmonella* serotypes were identified, including *S. muenchen*, *S. anatum* and *S. agona*. A total of 47 strains of Listeria were isolated from 4.4% Listeria-positive samples including *L. monocytogenes* (1.9%), *L. innocua* (2.1%) and *L. welshimeri* (0.6%). Some examples of the process stages where *Salmonella* may represent a hazard in dairy products are given in Table 3.2.

The toxins produced by *C. botulinum* are among some of the most potent, naturally occurring toxic substances known. If spores of *C. botulinum* are present in food and conditions are not inhibitory to germination and growth, the organism can proliferate and produce toxin. The organism is widespread in soil and aquatic sediments and also in the gastrointestinal tracts of animals, fish and birds (Bell and Kyriakides, 2000). The toxins produced by *C. botulinum* and affecting humans are neurotoxins which attack the nervous system of the affected individual. They block the release of acetylcholine, a neurotransmitter at the peripheral nerve ends. Transmission of nerve impulses at the neuromuscular junction is prevented and no muscle stimulation occurs, resulting in flaccid paralysis. The nature

Table 3.1 Examples of the process stages where Listeria monocytogenes may represent a hazard in dairy products.

Product	Raw material contamination	Reduction process	Destruction process	Post-process contamination	Product allows growth	Shelf life	Consumer cidal process
Pasteurised soft cheese (plain cottage cheese)	Yes	Yes	Yes	Yes	No	Yes	No
Pasteurised, ripened soft/semi-hard cheese (Camembert)	Yes	Yes	Yes	Yes	Yes	Yes	No
Pasteurised hard cheese (Cheddar)	Yes	Yes	Yes	Yes	No	Yes	No
Yoghurts	Yes	Yes	Yes	No	No	Yes	No
Raw milk, ripened soft cheese (category 1: highest)	Yes	No	No	Yes	Yes	Yes	No
Pasteurised, ripened soft cheese (category 2: high)	Yes	Yes	Yes	Yes	Yes	Yes	No
Pasteurised hard cheese (category 5: low)	Yes	Yes	Yes	Yes	No	Yes	No

and the properties of botulinum neurotoxins and their mode of action are subjects of study in their own right and further information may be found in Hauschild (1989); Shone (1987); Smith (1997); and Sugiyama (1980). Toxic doses for humans of all botulinum toxin types, however, are estimated to be very low, i.e. at levels of <1 μg for toxin types A and B and approximately 10 μg for toxin types E and F (Shone, 1987; Sugiyama, 1980). Three categories of botulism are recognised in humans; in addition to foodborne botulism, there are also wound botulism and infant botulism. Botulism may be easily misdiagnosed because symptoms resemble other illnesses (Bell and Kyriakides, 2000). Some examples of the process stages where *C. botulinum* may represent a hazard in dairy products are given in Table 3.3.

Since the 1920s, a great deal for more work has been carried out on serogrouping within *E. coli* and in the mid-1940s, a classification scheme was developed that allowed *E. coli* to be divided into more than 170

Table 3.2 Examples of the process stages where Salmonella may represent a hazard in dairy products.

Product	Raw material of animal origin	Raw material of poultry origin	Reduction process	Post-process contamination	Process allows growth	Destruction process	Consumer cidal process
Raw material ripened soft cheese (Brie, Camembert)	Yes	No	No	Yes	No	Yes	No
Raw milk hard cheese (Cheddar, Parmesan)	Yes	No	Yes	Yes	No	No	No
Pasteurised milk ripened soft cheese (Brie, Camembert)	Yes	No	Yes	Yes	Yes	Yes	No
Pasteurised milk hard cheese (Edam, Cheddar, Cheshire)	Yes	No	Yes	Yes	Yes	No	No
Pasteurised milk fermented products (yoghurt, fromage frais, cottage cheese)	Yes	No	Yes	No	Yes	No	No
Spray dried milk powder (infant dried milk)	Yes	No	Yes	Yes	Yes	No	No

Table 3.3 Examples of the process stages where Clostridium botulinum may represent a hazard in dairy products.

Product	Raw material contamination	Product formulation allows growth (NP/P)	Destruction process (NP/P)	Post-process contamination	Process allows growth	Shelf life	Storage restrictions required to prevent growth
Soft ripened cheese (Brie, Camembert)	Yes	Yes/yes	No/no	Yes	No	Yes	Yes
Hard cheese (Cheddar, Parmesan)	Yes	No/no	No/no	Yes	No	Yes	No
Acid fermented milk products (pH <4.7, yoghurt, clotted cream)	Yes	No/no	No/no	Yes	No	Yes	No
Low acid fermented/acidified milk products (pH >5, mascarpone, cream cheese)	Yes	Yes/yes	No/no	Yes	No	Yes	Yes
Processed cheese, chilled storage (cheese spread)	Yes	Yes/no	Yes/no	Yes	No	Yes	Yes
Processed cheese, ambient storage (processed cheese)	Yes	No/no	Yes/no	Yes	No	Yes	No
Heat processed, extended life, chilled dessert (mousse)	Yes	Yes/yes	Yes/no	Yes	No	Yes	No

different serogroups based on the somatic (O) antigens (Kauffmann, 1947). In addition, over 50 flagella (H) antigens and approximately 100 capsular (K) antigens (previously divided into L, A and B antigens) are now also recognised and these are used to further subdivide *E. coli* into serotypes (Linton and Hinton, 1988). The main raw material of concern in relation to *E. coli* O157 and other verocytotoxin-producing *Escherichia coli* (VTEC) is the raw milk itself. The key factors controlling the likelihood of contamination at this stage include the health of the animals and the hygienic precautions taken during milking (Beutin *et al.*, 1993). Padhey and Doyle (1991) reported a 10% (11/115) incidence of *E. coli* O157:H7 in raw milk, although a large study of raw milk, dairy and associated samples in the UK failed to detect the organism (Neaves *et al.*, 1994). A recently published survey of unpasteurised milk on sale in the UK found *E. coli* O157 in 3/1097 (de Louvois and Rampling, 1998).

Contamination from the animal is most likely to arise in two areas: first, from infection in the udder and shedding of organisms into the milk and second, from faecal contamination of the external surfaces of the udder. Although it is possible for *E. coli* to cause mastitis (Bramley and McKinnon, 1990), this is unlikely to be a frequent occurrence in relation to human pathogenic types such as VTEC. Mastitis of this nature can obviously be limited by appropriate animal husbandry practices that monitor the health of the animals and provide conditions under which such sources of infection can be reduced (Bell and Kyriakides, 1998).

Many manufacturers of raw milk cheese operate incentive payment schemes for their farmers based on the results of monitoring the hygienic status of the incoming raw milk. Indicators of contamination such as Enterobacteriaceae or *E. coli* may be monitored at frequent intervals in samples from each farm and from bulk milk tanks, and payment increased where good control is demonstrated and reduced for poor control (Bramley and McKinnon, 1990). Studies to date of the incidence of *E. coli* O157 rarely found evidence of extensive contamination in raw milk. This is not surprising as tests for pathogens that are likely to be intermittent contaminants, present at low levels and a low frequency, will rarely yield a positive result (Bell and Kyriakides, 1998).

A survey published by the Public Health Laboratory Service of England and Wales (Nichols *et al.*, 1996) found high levels of coliforms and *E. coli* in a number of cheeses. The type of *E. coli* found was not reported as tests for specific pathogenic strains were not carried out. In a study of 60 cheeses on retail sale in Iraq, Abbar (1988) reported the presence of *E. coli* in 43 samples with coliform counts ranging from 500 to

Table 3.4 Examples of the process stages where Escherichia coli may represent a hazard in dairy products.

Product	Raw material contamination origin	Raw material of bovine	Restructuring process	Destruction process	Post-process contamination growth	Process allows growth	Consumer cidal process
Raw milk ripened soft cheese	Yes	Yes	No	No	Yes	Yes	No
Raw milk hard cheese	Yes	Yes	Yes	No	Yes	No	No
Pasteurised milk ripened cheese, Brie	Yes	Yes	Yes	Yes	Yes	Yes	No
Pasteurised milk hard cheese (Cheddar, Edam)	Yes	Yes	Yes	Yes	Yes	No	No

26,000 per gram. In addition, four of the *E. coli* strains were identified as pathogenic serotypes (O119:K69, O125:K70, O86:K61 and O111:K58). The fact that *E. coli* is such a common contaminant in raw milk cheese and occasionally present at very high levels gives clear warning that the processes used do not eliminate the hazard, if present, in raw milk. In fact, it is clear that with levels of *E. coli* in raw milk usually at <100/mL and more frequently, at <10/mL, levels in excess of 100–1000/mL in the finished cheese products must be representative of growth and concentration or excessive contamination during processing (Bell and Kyriakides, 1998). Some examples of the process stages where *Escherichia coli* may represent a hazard in dairy products are given in Table 3.4.

Finally, probiotics, commonly defined as viable micro-organisms (bacteria or yeasts) that exhibit a beneficial effect on the health of the host when they are ingested, are used in foods, especially in fermented dairy products, but also in pharmaceutical preparations. The development of new probiotic strains aims at more active beneficial organisms. In the case of novel micro-organisms and modified organisms, the question of their safety and the risk to benefit ratio have to be assessed. Lactic acid bacteria (LAB) in foods have a long history of safe use. Members of the genera *Lactococcus* and *Lactobacillus* are most commonly given generally-recognised-as-safe (GRAS) status whilst members of the genera *Streptococcus* and *Enterococcus* and some other genera of LAB contain some opportunistic pathogens. LAB are intrinsically resistant to many antibiotics. In many cases resistances are not, however, transmissible, and the species are also sensitive to many clinically used antibiotics even in the case of an LAB-associated opportunistic infection. Therefore, no particular safety concern is associated with intrinsic type of resistance. Plasmid-associated antibiotic resistance, which occasionally occurs, is another matter because of the possibility of the resistance spreading to other, more harmful species and genera. The transmissible enterococcal resistance against glycopeptide antibiotics (vancomycin and teicoplanin) is particularly noteworthy as reported by Salminen *et al.* (1998), as vancomycin is one of the last effective antibiotics left in the treatment of certain multidrug-resistant pathogens. New species and more specific strains of probiotic bacteria are continuously identified. Prior to incorporating new strains into products their efficacy should be carefully assessed, and a case by case evaluation as to whether they share the safety status of traditional food-grade organisms should be made.

These micro-organisms can produce a wide variety of antagonistic primary and secondary metabolites including organic acids, diacetyl, CO_2 and even antibiotics such as reutericyclin produced by *Lactobacillus reuteri*. Moreover, members of the group can also produce a wide range of bacteriocins, some of which have activity against food pathogens such as *Listeria monocytogenes* and *C. botulinum*. Indeed, the bacteriocin nisin has been used as an effective biopreservative in some dairy products for decades, while a number of more recently discovered bacteriocins, such as lacticin 3147, demonstrate increasing potential in a number of food applications. Both of these lactococcal bacteriocins belong to the lantibiotic family of post-translationally modified bacteriocins that contain lanthionine, β-methyllanthionine and dehydrated amino acids. The exploitation of such naturally produced antagonists holds tremendous potential for extension of shelf life and improvement of safety of a variety of foods (Ross *et al.*, 2002).

Ln. mesenteroides subsp. *cremoris* or *Ln. lactis* strains are of classical use in butter and cream or fresh cheese production and some fermented fresh dairy products (Vedamuthu, 1994). The presence of *Leuconostoc* in numerous cheese varieties made without addition of *Leuconostoc* starter is regular, in particular in raw milk cheeses. Previous data have confirmed the

presence of *Leuconostoc* in the majority of raw milk French cheeses and other European cheeses (Devoyod and Poullain, 1988).

The role of *Ln. mesenteroides* subsp. *cremoris* in aroma production has been well described by Vedamuthu (1994). In pressed ripened Dutch cheeses such as Edam, Gouda and other brine salted cheese varieties, small and shiny openings are due to CO_2 produced by *Leuconostoc* present in the starter. The major compound related to the utilisation of *Leuconostoc* in the dairy field is diacetyl, acetate for thioester and ethanol for ester production (Crow *et al.*, 2002) contributing also to aroma formation (Vedamuthu, 1994) in cheeses in which methane thiol is present (Hemme and Foucaud-Scheunemann, 2004). Alternatively, *Leuconostoc* could be used in the conversion of acetaldehyde to ethanol and acetate (Liu *et al.*, 1997).

Genetic modifications such as one-step genetic events like deletions, gene amplifications, plasmid insertions or losses; multi-step genetic rearrangements with DNA of a same species; and trans-species genetic modifications illustrate the vast potential LAB have for present and future applications in various domains of the dairy industry (Mollet, 1999). They will continue to play an important role in the fermentation processes of a variety of different food products by contributing to their conservation, flavour development, texture and health beneficial properties. Increasingly, they will also be used as a natural source of food ingredients and additives to non-fermented products to attain, for example organoleptic, texturing or probiotic aims. The progress in molecular biology and genetic engineering will broaden the possibilities for using LAB in food and may also allow the improvement of existing products and the development of novel products and applications.

LAB have a long history of safe use in fermented food products. They are considered non-toxic and were not reported as the causative agents in disease or infection. Nevertheless, all newly isolated or genetically altered LAB and their resultant fermented foods have to be carefully evaluated for their safety to the consumer and environment. They are subjected to stringent safety and regulatory procedures in the same way as do all new food products which are commercialised and sold to the consumer. In fact, it was only with the help of molecular biology that it became possible to correctly classify and differentiate the diverse species of the LAB to better identify their origins, natural habitats and dissemination in nature and in the intestines of humans and animals. This knowledge and the possibility to trace individual strains along the food chain and the digestive tract further contribute to the better evaluation of potential risk factors and finally add to their confidence and safety. The intelligent, responsible development and use of genetically improved micro-organisms led us to the new millennium bringing exciting new products to the consumer (Mollet, 1999).

Exposure to mycotoxins through food is widely recognised as a human health hazard (Bhat and Vasanthi, 1999). Of all the mycotoxins, Aflatoxin B1 (AFB1) is considered to be the most toxic/carcinogenic compound (IARC, 1993). It is biotransformed by hepatic microsomal cytochrome P450 to Aflatoxin M1 (AFM1) which possesses ten times lower carcinogenic potential with respect to the parent molecule (Cullen *et al.*, 1987) and has been listed as class 2B carcinogen (Smith *et al.*, 1994). AFM1 has been shown to be excreted in milk following exposure to AFB1 contaminated feed (Heathcoate and Hibbert, 1978). The consumption of milk and milk products by the human population is quite high, particularly among infants and young children thereby increasing the risk of exposure to AFM1. Since milk is a major commodity for introducing aflatoxins in the human diet, the occurrence of AFM1 in this product is of concern (Stoloff, 1980). Evidence of hazardous human exposure to AFM1 through dairy products has been shown by several investigators (Galvano *et al.*, 1996).

Regulatory limits throughout the world are greatly influenced by economic considerations and may vary from one country to another (Stoloff *et al.*, 1991). The European Community and Codex Alimentarius prescribe that the maximum level of AFM1 in liquid milk and dried or processed milk products should not exceed 50 ng/kg (Codex Alimentarius Commission, 2001). This limit has been established in compliance with the ALARA (as low as reasonably achievable) principle.

The occurrence of AFM1 contamination in Indian infant milk products and liquid milk samples was investigated by competitive ELISA technique (Rastogi *et al.*, 2004). A total of 87 samples in categories of infant milk food (18), infant formula (17), and milk-based cereal weaning food (40) and liquid milk samples (12) showed that the incidence of contamination of AFM1 was of the magnitude of 87.3%. The range of contamination of AFM1 was comparatively higher in infant milk products (65–1012 ng/L) than liquid milk (28–164 ng/L). Almost 99% of the contaminated samples exceeded the European Communities/Codex Alimentarius recommended limits (50 ng/L), while 9% samples of exceeded the prescribed limit of US regulations (500 ng/L). The extrapolation of AFM1 data to estimate the AFB1 contamination in dairy cattle feedstuffs indicated that the contamination may range from 1.4 to 63.3 μg/kg with a mean of 18 μg/kg which

is substantially higher than the directive of European Communities Regulation (5 μg/kg).

More than two million metric tonnes of ewe's milk is produced in the European Union (EU), with Italy, Greece and Spain being the largest producers (Herrero, 1999). Cheese making is one of the main uses of ewe's milk, as is demonstrated by the fact that in Spain ewe milk cheeses account for 40% of total cheese consumption (ILE, 1999). Many of these cheeses are manufactured from raw milk at small, artisan cottage cheeseries in accordance with regulations established and supervised by a Designation of Origin.

The microbial quality of cheeses made from raw ewe's milk will depend both on the quality of the raw material and on the cheese-making process. The microbiological characteristics of ovine milk differ from bovine milk in certain respects. Such factors as the larger number of head per volume of milk production, the seasonality of production, the large number of head per flock, feeding, the milking process, etc., all increase the difficulty of establishing good sanitary practices during milk production.

The microbiological standard set by the Directive 71/96/EC indicated a maximum permissible total count of 5×10^5 cfu/mL for raw ewe milk intended for direct use in cheese making. For milk that does not comply with that standard, pasteurisation is the primary means of ensuring that the cheeses will not represent a health risk. Still, industrial pasteurisation cannot guarantee the absence of pathogenic micro-organisms, either because they are present in large numbers in the raw milk, or because of post-pasteurisation recontamination. In addition, pasteurisation reduces a large proportion of the lactic acid flora and secondary flora that may play an important role in the development of many desirable characteristics in cheeses.

Counts of micro-organisms with health and technological implications (total aerobic mesophiles, Enterobacteriaceae, total coliforms, faecal coliforms, *E. coli*, *Enterococcus*, *Staphylococcus*, *Lactobacillus*, *Leuconostoc*, *Pseudomonas*, *Clostridium tyrobutyricum*, moulds and yeasts) in raw and pasteurised ewe's milk were performed over the course of one lactation period (winter, spring and summer) by Salmeron *et al*. (2002). Seasonal differences in the counts were recorded for ten of the micro-organism groups considered, the highest counts being in spring. In contrast, the highest counts in the pasteurised milk were recorded in summer, because of lower effectiveness of pasteurisation at that time of the year. Reductions in the counts of the different micro-organism groups were likewise variable. The presence of micro-organisms that may pose a health threat in the pasteurised milk highlights the need for post-pasteurisation controls.

Enterococci commonly occur in milk and milk products, especially in artisan cheeses from the Mediterranean area. They may be present in high numbers in a variety of such cheeses at the end of the ripening period and contribute to ripening and aroma development (Franz *et al*., 1999a; Giraffa, 2002). This has led to the suggestion that enterococci might have been included in starter culture preparations for the manufacture of certain Mediterranean cheeses (Centeno *et al*., 1996; Parente *et al*., 1989). Furthermore, they have been isolated from Spanish-style green olive fermentations (Fernández-Diaz, 1983), in which *E. faecalis* is a frequent contaminant.

One special benefit of the presence of enterococci in food is that such strains may also produce bacteriocins (the enterocins). Some enterococci of dairy origin have also been reported to produce bacteriocins (enterocins) inhibitory against food spoilage or pathogenic bacteria, such as *Listeria monocytogenes*, *S. aureus*, *Vibrio cholerae*, *Clostridium* spp. and *Bacillus* spp. The technological application of enterocins, shown to be produced during cheese manufacture, led to propose enterococci as adjunct starters or protective cultures in cheeses. There is evidence that enterococci, either added as adjunct starters or present as non-starter NSLAB, could find potential applications in the processing of some fermented dairy products. Literature suggests that the complex biochemical and ecological phenomena explaining the technological functionality of the enterococci in dairy products are still to be fully understood. Clearly, the clinical research on enterococci underlines also that the safety of dairy products containing enterococci is an issue that the industry must carefully address before proceeding to their application (Giraffa, 2003).

Most enterococcal bacteriocins belong to class II of the Klaenhammer classification (Klaenhammer, 1993), although they exhibit a considerable diversity. In addition, enterocins other than those which belong to the class II bacteriocins are also produced and these include the class I lantibiotic cytolysin, as well as cyclic enterocin AS-48 (González *et al*., 2000). Many enterococcal bacteriocins are active against the foodborne pathogen *Listeria monocytogenes*, while others (like enterocin AS-48) show a much broader inhibitory spectrum, including pathogenic, toxigenic and food spoilage bacteria (Gálvez *et al*., 1989). Consequently, the enterocins have become attractive in recent years as natural additives for food preservation and safety. Although they occur as commensals of the gastrointestinal tract of warm-blooded animals, enterococci may also display subtle virulence traits (Mundy *et al*., 2000) and certain strains of enterococci have emerged as leading causes of nosocomial infection,

including urinary tract infections, wound infections and bacteraemia.

The role of enterococci in disease has raised questions regarding their use in foods or as probiotics. Recent studies on the incidence of virulence traits among food strains showed that food isolates can also harbour such traits (Franz *et al*., 2001).

The results presented by Omar and his co-workers (2004) suggested that the presence of enterococci in Spanish foods does not represent a threat to human health. The large differences reported on the incidence of virulence factors among isolates from foods and the reports on clinical isolates clearly indicate that the environment plays a critical role in selection of the best suited strains. Accordingly, enterococcal strains isolated from foods seem to be equipped with biochemical traits that allow them survival and proliferation in foods and (probably) to displace virulent and food spoilage strains. Nevertheless, the safety of enterococci in foods may be compromised by the acquisition of antibiotic resistance traits, and further studies should be carried out to determine the traffic of antibiotic resistance genes and movable genetic elements between strains from food and clinical environments.

L. monocytogenes is widely distributed in the farm (soil, manure, plants and water) and in the industrial and human food chain environment. Since the early 1980s, outbreaks have been associated with a lot of ready-to-eat foods, including coleslaw, milk and cheese (pasteurised or not), pate and pork tongue in jelly.

Estimates of the yearly incidence of human listeriosis range from <2–12 per 106 persons (Low and Donachie, 1997) and display a decreasing trend over the past decade, both in North America (Tappero *et al*., 1995) and in Europe (Goulet *et al*., 2001; PHLS, 1998). Public warnings enabling susceptible numbers of the population to avoid high-risk foods may have contributed to reduce the number of reported cases, especially in the pregnant female population. Host susceptibility remains, however, an important factor in infection (Goulet *et al*., 2001). The fall in numbers of reported cases of human listeriosis has demonstrated the efficacy of both veterinary inspection procedures and corrective measures based on the Hazard Analysis Critical Control Point (HACCP) approach taken on production lines and stores since the early 1990s (Goulet *et al*., 2001).

In France, absence of *L. monocytogenes* in 25 g is compulsory for the finished product (raw milk cheese) but not for the raw milk on reception at the plant. However, French cheese plants must have HACCP monitoring and must communicate internal control results regularly to public health services. Sampling strategies for *Listeria* control in raw milk vary between plants, as a function of the number of farms to be monitored, cost of analytical method and corrective strategy in case of pathogen detection. Monitoring can be made in different ways: (i) on each farm (bulk tank) at each raw milk collection, (ii) on each milk tanker, with subsequent examination of bulk tanks in case of contamination or (iii) with more elaborate sampling schemes designed for a global quality evaluation of each farm. Strategies (i) and (ii) are very expensive, but make it possible to target corrective actions to contaminated farms. The last strategy (iii) is used mainly by plants with large pool of farms, in which the best sanitary status farms are selected for raw milk cheese production (Meyer-Broset *et al*., 2003). These authors confirmed that farm milk contamination is, most often, a sporadic event. In addition to this prevalence study, contamination levels were quantified by enumerating *L. monocytogenes* using direct plating of small volumes of farm milk previously tested positive. Most often, these levels were extremely low. A simple simulation model showed that, when milk tankers were found positive, contamination levels in the corresponding bulk-tank milk were themselves very low (typically, below 3 *L. monocytogenes* per millilitre with most probable concentration 0.1cfu/mL and median ranging from 5×10^{-2} to 0.1 cfu/mL). Such low levels are very likely to be due to environmental contamination.

Hassan *et al*. (2001) carried out a cross-sectional study to identify farm factors associated with isolation of *L. monocytogenes* from on-farm in-line milk filters. Logistic regression was used to find that a bucket system had higher odds of *L. monocytogenes* compared to farms using a round-the-barn pipeline milking system or milking parlour. Among modern techniques, the Petrifilm system (3M, Microbiology Products), for enumerating total aerobic mesophilic microorganisms, has been proposed as a substitute to standard plate count. These plates consist of two rehydratable films that contain the necessary nutrients for bacterial growth, a soluble gel, and, to facilitate colony enumeration, tetrazolium as an indicator.

The direct epifluorescent filter technique (DEFT) for micro-organism enumeration combines staining of micro-organisms with fluorochromes and observation using epifluorescence microscopy. Pettipher and Rodriguez (1982) described it, and it rapidly gained the acceptance of the scientific community (Fung, 1994; Patel, 1994; Pettipher, 1986). Among its advantages the most important are: speed (full analysis within 25–30 minutes), sensitivity (it detects three or four higher magnitude ranges than direct microbiological observation), accuracy (results showed good correlation coefficient compared to standard methods)

and possibility of distinction between dead and living bacteria.

Rosmini *et al.* (2004) evaluated the advantages of two microbiological rapid techniques (Petrifilm plates and DEFT), applied to enumerating total aerobic mesophilic micro-organisms in refrigerated raw milk supplied by dairy farms, compared to the reference technique (standard plate count) considering results correlation, costs and needed time for results to be available.

The two alternative techniques under study showed good correlation levels with the standard in plate technique. The dry rehydratable film technique had higher costs but this technique allows the analysis of twice the quantity of samples in the same unit of time compared to the standard plate technique. This compensates for the higher costs. The epifluorescent technique gave the results in shorter time but it is necessary to use sophisticated equipment and trained personnel. Therefore, it is preferred when having the appropriate infrastructure. The most important risk factors are antibiotics and dioxin for chemical food safety, and *Salmonella*, *E. coli*, *S. aureus* and *Mycobacterium paratuberculosis* for microbiological food safety (Valeeva *et al.*, 2005).

Valeeva *et al.* (2005) assessed the relative importance of 30 preventive measures for chemical and microbiological food safety at farm level. On the basis of these assessments indices for chemical and microbiological food safety were calculated by van Calker *et al.* (2006). The workers' physical health and societal sustainability indicators were successfully included in a dairy farm LP model. The model offers the opportunity to analyse differences between and within dairy farming systems with respect to the level of economic and social sustainability. They concluded therefore that the societal sustainability performance of conventional as well as organic dairy farming systems can be improved by applying additional management measures.

Bovine viral-diarrhoea (BVD), enzootic bovine leucosis (EBL), Johne's disease (JD) and neosporosis are common infectious diseases on dairy farms in Canada and elsewhere. A more recent survey found that 37.6, 20.8, 2.6 and 20.3% of a random sample of dairy cattle in the Maritimes provinces of Canada were seropositive to the agents that cause BVD (in cattle not vaccinated for BVD), EBL, JD and neosporosis, respectively (VanLeeuwen *et al.*, 2001).

Chi *et al.* (2002) determined the relationship between various control practices and herd-level prevalence of exposure with the agents causing four production-limiting diseases in dairy cattle (BVD, EBL, JD, neosporosis) in 90 dairy herds in the Maritimes provinces of Canada. Overall, 37.8, 20.4, 3.4 and 19.2% of all sampled cattle were truly exposed to the agents of BVD, EBL, JD and neosporosis, respectively. For EBL, because bovine leukaemia virus is primarily horizontally transmitted by blood (virus-infected lymphocytes), vaccination is like a surrogate measure of good management where needles are not reused (thereby reducing other sources of blood transfer). Tobit regression analyses determined that vaccination practices were associated with reduced prevalence of exposure for BVD and EBL. Also, farms that tended to purchase their dairy animals were associated with higher seroprevalence for JD.

Kan and Meijer (2007) reported that toxic substances such as dioxins, mycotoxins, heavy metals, pesticides, veterinary drugs and polycyclic aromatic hydrocarbons are also present in ingredients for animal feed. Adequate risk management depends on knowledge of absorption, metabolism, carry-over and toxicological profile of these substances and on practical measures to reduce especially the latter two. Generally, toxic substances are metabolised before or after absorption through the intestinal tract. Depending on their physicochemical characteristics, some substances such as veterinary drugs and feed additives are metabolised into naturally occurring and generally harmless constituents. Other substances like dioxins are persistent and remain in the animal and in animal products. Heavy metals are not metabolised at all. Some metals are irreversibly bound to body tissues, e.g. lead to bone or cadmium to kidneys.

Exposure prevention is by far the preferred risk management tool. Known contaminants from known sources can be handled effectively in this way, an example being the reduction in organochlorine and heavy metal residue levels in poultry. Use of adsorbents has been tested extensively both for organochlorine compounds and for mycotoxins. Heavy metal and drug contamination of feeds are also to be controlled at the feed mill, by selection of feed ingredients and through proper manufacturing practices. Mycotoxin control is quite hard to be executed as weather conditions play a pivotal role in fungal growth and mycotoxin formation. Absorbents added to the feed may sometimes alleviate the problem. Withdrawal times should be followed if prescribed legally and may in some instances provide a solution. In the case of milk and eggs, produced on a daily basis, the animal products are most likely to show increased residue levels during prolonged exposure (Kan and Meijer, 2007).

Reduction in contamination levels due to dilution as a result of growth will also help to obtain a product in compliance with legal residue limits. On-farm HACCP programmes for monitoring antibiotic residues are costly to implement as reported by Gardner (1997).

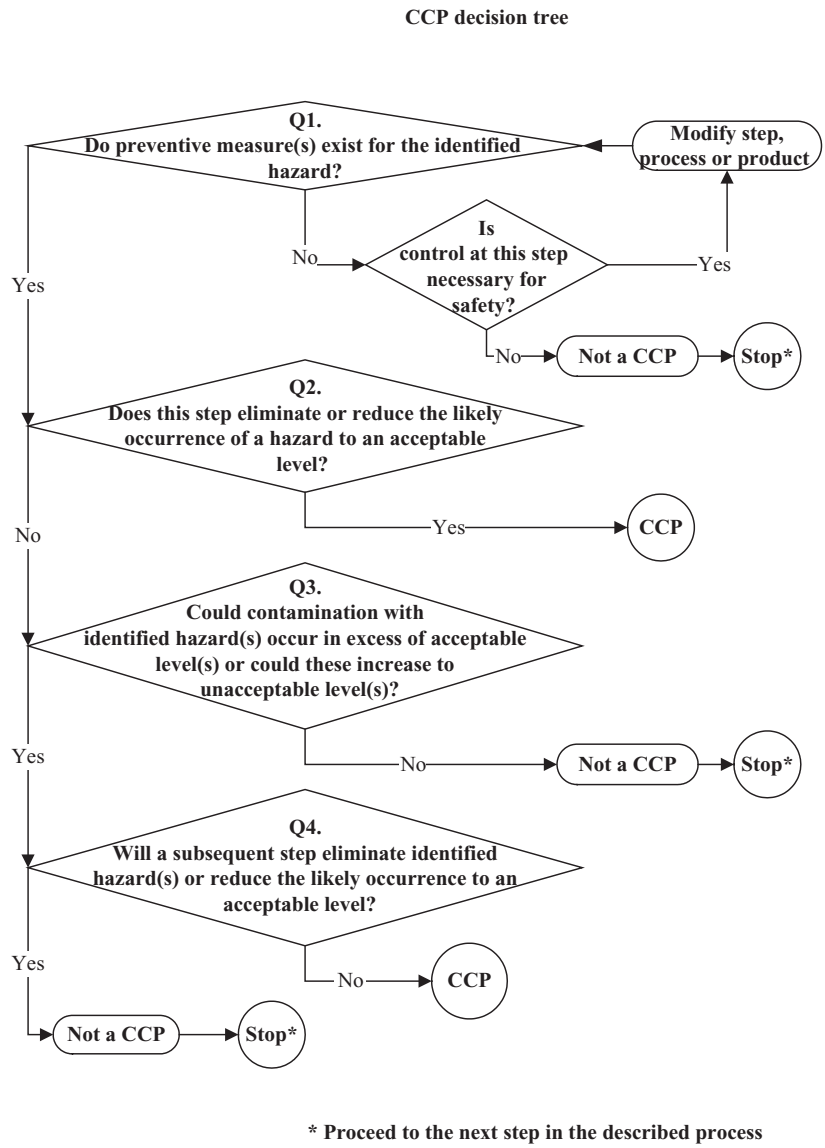

Fig. 3.1 Tree diagram for CCP determination.

The estimated annual cost of testing to detect β-lactam antibiotic residues in tanker truck milk in the United States is between $8 and $35 million. Extension of testing to other drugs, chemicals and pathogens in bulk-tank milk stretch the dairy industry resources. The lack of field-validated tests for most of the chemical and infectious agents of concern makes it difficult to ensure that stated goals of HACCP programmes are consistently achieved. Much basic and field research is needed to develop and validate these tests, which can only be achieved through a substantial infusion of new research funding. Validation of tests is essential for selection of the most appropriate testing strategies, to estimate predictive values and for appropriate test interpretation. The determination of the numbers of samples to be tested in HACCP monitoring programmes depends on the specific purpose of the test and the likely prevalence of the agent or residue at the critical control point (CCP). The tree diagram for CCP detection is given in Fig. 3.1 and the raw materials and hazard analysis of raw materials are summarised in Tables 3.5 and 3.6, respectively.

Plant-associated toxins can enter the human food supply as endogenous components of the food humans eat, as contaminants in foods such as grain products and honey, or as contaminant residues in animal-derived food such as meat, dairy products and eggs. Animals are exposed to these toxins via normal grazing and browsing, or being supplied with otherwise healthy feed contaminated by toxin-producing plants or plant-associated micro-organisms.

To protect animal health, welfare and productivity there is an ongoing need to elucidate the factors associated with intoxication, chemically identify the causative toxins and then develop assay methodology to allow the assessment of animal feed for potential toxicity. Three classes of plant-associated toxins, i.e. the phomopsins, corynetoxins and pyrrolizidine alkaloids have been detected and quantified by Than *et al.* (2005).

A risk-factor study was performed by Rugbjerg *et al.* (2003) in eight dairy herds found to excrete Verocytotoxigenic E. Coli 0157 (VTEC O157) in a former prevalence study. Associations between excretion of VTEC O157 and management factors such as housing and feeding were analysed in a generalised linear mixed model. The animals were stratified in three age groups and sampled four times during 1 year. The risk of excreting VTEC O157 was higher among weaned calves than non-weaned calves.

Among the calves aged 1–4 months, the risk was reduced if the calf had suckled colostrum from the mother or if the calf had stayed >2 days with the mother after calving. Calves aged 5–24 months that had been moved within the last 2 weeks had a higher risk, but risk was reduced if fed barley silage. Cows fed grain or molasses had a higher risk of excreting VTEC O157.

Table 3.5 Raw materials.

Raw materials	Description
Milk Cow Goat Sheep	Fresh
Other raw materials Salt Cultures Rennet Calcium chloride	Packaged/suitable for food
Water	Potable water
Packaging materials Tin cans Bags Paraffin	Food grade

3.2 INTRODUCTION TO DAIRY INDUSTRY

The HACCP system was developed to help manufacturers produce safe food. It is designed to identify hazards and to establish and monitor controls. An HACCP plan proves that the controls are in place and that the system is functioning effectively (FAO, 1998). The dairy industry presents a unique and complex problem for the implementation of HACCP. The starting point is raw milk collected from a living animal with all the hazards associated with such working conditions; however, the problem then widens as a result

Table 3.6 Hazard Analysis of raw materials.

Raw materials	Biological hazard	Chemical hazard	Physical hazard
Milk	Presence of pathogenic micro-organisms: *Listeria monocytogenes*, *Yersinia enterocolitica*, *Campylobacter jejuni*, *Bacillus cereus*, *Salmonella* spp., *Staphylococcus aureus*, *E. coli* (O157:H7)	Antibiotic residues	Foreign matter
		Detergent remnants	
	Shigella spp., *Mycobacterium* spp., *Brucella* spp., *Bacillus anthracis*, Streptococcus, *Clostridium botulinum*, *Clostridium perfringens*	Presence of mycotoxins	
	Viruses		
	Increased temperature during receipt of milk (>6°C): This means danger for microbial growth and multiplication of pathogenic micro-organisms	Increase in pesticide residues, dioxins, PCBs	
Salt	Increased moisture, contamination	Heavy metals	Foreign matter
Enzymes/ micro-organisms	Contamination, genetically modified organisms		

of subsequent treatment. In some cases the milk may be pasteurised or sterilised or subjected to ultra-high-temperature (UHT) treatments, each of which brings a different combination of challenges to the food scientist. In other cases, the milk may be used in its raw state thereby giving rise to different challenges associated with the microflora and bacterial contaminants found in the milk. Further to this, the use of milk in various modified forms, cheese, cream, butter, yoghurt etc. results in yet further processing and a range of different scenarios for the food technologist implementing HACCP. To further complicate the problems the production of certain milk-based foods involves fermentation, storage under precise conditions and the deliberate addition of a range of bacteria or moulds on which the flavour and quality of the final product are dependent. In this chapter, an attempt is made to describe the planning needed in the various industries associated with the production of the wide range of dairy products.

Numerous micro-organisms, including bacteria, yeasts and moulds, constitute the complex ecosystem present in milk and fermented dairy products. Bacteria in the unknown ecosystems were assigned an identity by comparison with a comprehensive bacterial reference database of approximately 150 species that includes useful dairy micro-organisms (lactic acid bacteria), spoilage bacteria (e.g. *Pseudomonas* and Enterobacteriaceae) and pathogenic bacteria (e.g. *Listeria monocytogenes* and *S. aureus*) (Ogier *et al.*, 2004). Numerous dairy products are home to a complex microbial ecosystem, which is responsible for the broad diversity of tastes, aromas and textures that are associated with them. Many bacteria make a positive contribution to the organoleptic qualities of cheeses or fermented milk, while others may have adverse effects or even constitute a health risk. Cheese processing is largely based on fermentation by LAB, which are both deliberately added as starter cultures or adventitiously present in the biotope and selected during the fermentation process. Furthermore, raw milk bacteria, including non-starter LAB, reportedly enhance cheese flavour and diversity (Martley and Crow, 1993). Ripened cheeses are characterised by a succession of largely undefined microbial communities on their surface. These aerobic micro-organisms have a strong impact on the appearance, odour, flavour and texture development of the respective cheese products (Brennan *et al.*, 2002). Non-desirable micro-organisms, such as the psychotropic *Pseudomonas fluorescens* (Stevenson *et al.*, 2003) or certain proteolytic LAB may cause flavour defects (e.g. bitterness and putrid flavours) in milks and cheeses (Celestino *et al.*, 1996). The presence of *E. coli*, *Listeria monocytogenes* and *S. aureus* in raw milks and cheeses constitutes a health risk (Meyer-Broseta *et al.*, 2003).

The microbial quality of raw milk is crucial for the production of quality dairy foods. Spoilage is a term used to describe the deterioration of a food's texture, colour, odour or flavour to the point where it is unappetising or unsuitable for human consumption. Microbial spoilage of food often involves the degradation of protein, carbohydrates and fats by the micro-organisms or their enzymes. In milk, the micro-organisms that are principally involved in spoilage are psychotropic organisms. Most psychrotrophs are destroyed by pasteurisation temperatures; however, some like *Pseudomonas fluorescens* and *Pseudomonas fragi* can produce proteolytic and lipolytic extracellular enzymes which are heat stable and capable of causing spoilage (http://www.foodsci.uoguelph.ca/dairyedu/micro.html#micro3).

Some species and strains of *Bacillus*, *Clostridium*, *Corynebacterium*, *Arthrobacter*, *Lactobacillus*, *Microbacterium*, *Micrococcus* and *Streptococcus* can survive pasteurisation and grow at refrigeration temperatures which can cause spoilage problems. The following bacterial pathogens are still of concern today in raw milk and other dairy products: *Bacillus cereus*, *Listeria monocytogenes*, *Yersinia enterocolitica*, *Salmonella* spp., *E. coli* O157:H7 and *Campylobacter jejuni*. It should also be noted that moulds, mainly of species of *Aspergillus*, *Fusarium* and *Penicillium*, can grow in milk and dairy products. Under favourable conditions, these moulds may produce mycotoxins which can be a health hazard (http://www.foodsci.uoguelph.ca/dairyedu/micro.html#micro4).

With the exception of soft cheese and pasteurised milk products, processed dairy products have an excellent history of safety with regard to listeriosis. The only reported incident to date associated with other dairy products occurred in Belgium, where listeriosis was said to be associated with the consumption of ice cream made with fresh cream in a restaurant (McLauchin, 1996). Like ready-meals, this low association with listeriosis probably relates to the fact that fresh dairy desserts usually have an extremely short shelf life of less than 5 days because of the spoilage of the product that could occur by other contaminating micro-organisms if the shelf life was much longer (Bell and Kyriakides, 2005).

Indeed, it is believed that the sharp rise in cases in the period between 1987 and 1989 was due to a foodborne outbreak associated with contaminated pâté from a single Belgian manufacturer (McLauchin *et al.*, 1991). *Listeria monocytogenes* is widespread in the environment and, consequently, can be found in a wide variety of raw foods (Table 3.7). The organism is transmitted to humans via three main routes: contact with

Table 3.7 Incidence of micro-organisms reported in dairy products.

Food	Country	Micro-organism	Incidence	Reference
Raw cows' milk from farm bulk tanks	USA	*Listeria monocytogenes*	12	Rohrbach *et al.* (1992)
Raw cows' milk from farm bulk tanks	UK	*Listeria monocytogenes*	102	O'Donnell (1995)
Raw cows' drinking milk	UK	*Listeria monocytogenes*	32	Bell and Kyriakides (2005)
Raw caprine milk	Spain	*Listeria monocytogenes*	37	Gaya *et al.* (1996)
Soft and semi-soft cheeses	Sweden	*Listeria monocytogenes*	20	Loncarevic *et al.* (1995)
Cheeses	USA	*Listeria monocytogenes*	42	Gombas *et al.* (2003)
Prepared retail foods including cheese products 1997	Denmark	*Listeria monocytogenes* (present at >10 per gram)	760	Norrung *et al.* (1999)
Prepared retail foods including cheese products 1998	Denmark	*Listeria monocytogenes* (present at >10 per gram)	670	Norrung *et al.* (1999)
Ice cream imported	Korea	*Listeria monocytogenes*	8	Baek *et al.* (2000)
Pasteurised milk	USA	*Listeria monocytogenes*	49 (14 deaths)	Fleming *et al.* (1985)
Vacherin cheese	Switzerland	*Listeria monocytogenes*	122 (34 deaths)	Bula *et al.* (1995)
Chocolate milk	USA	*Listeria monocytogenes*	45	Dalton *et al.* (1997)
Raw milk soft cheese	France	*Listeria monocytogenes*	20 (4 deaths)	Goulet *et al.* (1995)
Butter	Finland	*Listeria monocytogenes*	25 (6 deaths)	Maijala *et al.* (2001)
Butter	UK	*Listeria monocytogenes*	14	Bell and Kyriakides (2005)
Pasteurised flavoured milk	USA	*Listeria monocytogenes*	45	Bell and Kyriakides (2005)
Hazelnut yoghurt (contaminated and toxic canned hazelnut conserve component)	UK	*Clostridium botulinum*	27 (1 death)	Critchley *et al.* (1989); O'Mahony *et al.* (1990)
Canned cheese sauce	USA	*Clostridium botulinum*	8 (1 death)	Townes *et al.* (1996)
Mascarpone cheese (acidified dairy cream)	Italy	*Clostridium botulinum*	8 (1 death)	Aureli *et al.* (1996)
Cheddar cheese	USA	*Salmonella*	339	Fontaine *et al.* (1980); D'Aoust (1989)
Raw milk	Scotland	*Salmonella*	654	Cohen *et al.* (1983)
Cheddar cheese	Canada	*Salmonella*	1500	D'Aoust *et al.* (1985)
Pasteurised milk	USA	*Salmonella*	16,284	Lecos (1986); Ryan *et al.* (1987)
Vacherin Mont d'Or cheese	Switzerland	*Salmonella*	>40	Sadik *et al.* (1986)
Infant dried milk	UK	*Salmonella*	76	Rowe *et al.* (1987)
Mozzarella	USA	*Salmonella*	164	Hedberg *et al.* (1992)
Unpasteurised milk soft cheese	UK	*Salmonella*	42	Maguire *et al.* (1992)
Goat's milk cheese, unpasteurised	France	*Salmonella*	273	Desenclos *et al.* (1996); Threlfall *et al.* (1999)
Unpasteurised milk soft cheese product	Canada	*Salmonella*	35	Ellis *et al.* (1998)
French cheese	France and Switzerland	*Salmonella*	25	Vaillant *et al.* (1996)

(*Continues*)

Table 3.7 (Continued)

Food	Country	Micro-organism	Incidence	Reference
Raw milk soft cheese – Morbier	France	*Salmonella*	113	De Valk *et al.* (2000)
Pasteurised milk	UK	*Salmonella*	86	Bell and Kyriakides (2002)
Spray dried milk powder used for infant formula	UK	*Salmonella*	76 (1 death)	Bell and Kyriakides (2002)
French Brie cheese	USA, Denmark, the Netherlands and Sweden	*Escherichia coli*	169	Padhey and Doyle (1991); MacDonald *et al.* (1985)
French Brie cheese and Camembert cheese	USA	*Escherichia coli*	387	Marier *et al.* (1973)
Yoghurt	UK	*Escherichia coli*	16	Morgan *et al.* (1993)
Dairy herds	UK	*Escherichia coli*	13	Zhao *et al.* (1995)
Fresh pasteurised liquid milk	Scotland	*Escherichia coli*	69	Bell and Kyriakides (1998)

animals, cross-infection of newborn babies in hospital and foods. *Listeria monocytogenes* is found within the normal human intestinal flora as part of the transient or resident population. Two to six per cent of healthy people are reported to be asymptomatic carriers of *L. monocytogenes*. In a study of 147 healthy pregnant women, a faecal carriage rate of 2.7% was found over the time of the study (Gray *et al.*, 1993). Wild and domestic animals are known to carry *L. monocytogenes*, and many can become infected and suffer listeriosis. Most farm-associated incidents occur in the form of skin infections of farmers and veterinarians acquired by direct contact with infected animals (Bell and Kyriakides, 2005).

The properties and the significance of the principal indigenous enzymes in milk, milk coagulants, enzymes from dairy micro-organisms participating in cheese ripening, and spoilage enzymes such as lipases, phosphatases, enzymes from somatic cells, enzymes involved in antimicrobial and antiviral systems in milk, enzymes from LAB, propionibacteria and micro-organisms involved in smear- and mould-ripened cheese were reviewed by Stepaniak (2004). *Brevibacterium linens* is an important species in dairy products rendering a specific taste and aroma to numerous smear ripened and blue-veined cheeses due to proteolysis. However, the presence of the species in South African blue-veined cheeses is undesirable and consumers require a product void of the species. Accordingly, numerous methods including microbial inhibition using fungi and bacterial probiotic cultures with possible inhibitory effects were applied in an attempt to inhibit the species. None of the fungi, however, proved to be successful, whereas *Lactobacillus rhamnosus* and *Bifidobacterium lactis*, two typical probiotic species applied in dairy products, displayed strong inhibitory effect against *B. linens* when tested using the spot-on-lawn assay (Knox *et al.*, 2005).

3.3 ENZYMES IN DAIRY PRODUCTS

It is well known that a part of the world population suffers from lactose intolerance (Kretchmer, 1972). These people cannot benefit from the nutritional quality of milk and milk-derived products without having serious intestinal problems. Pre-treatment of the milk with the enzyme lactase (β-galactosidase) converts lactose into galactose and glucose. These mono-sugars can be consumed without any problem even by humans with lactose intolerance.

The US Food and Drug Administration (FDA) affirmed lactase preparations, produced by *Kluyveromyces lactis* (formerly known as *Saccharomyces lactis*) as Generally Recognised As Safe (GRAS) in 1984 (FDA, 1984). Maxilact, the DSM brand name of a lactase preparation produced by the classical strain of *K. lactis*, has already been on the market for decades and has a history of safe use (AMFEP, 1997). Its safety evaluation was based on an LD50, a 14-day subacute and a 90-day subchronic toxicity study in rats.

Neutralact, the DSM brand name of a lactase enzyme preparation, obtained from a homologous rDNA strain of *Kluyveromyces lactis*, was subjected to a series of toxicological tests to document the safety for use as a processing aid in the dairy industry (Coenen *et al.*, 2000). The enzyme preparation was examined for subacute oral toxicity and mutagenic potential. As a result of these tests, no evidence of oral toxicity, mutagenicity or clastogenicity was found. Administration

Table 3.8 Feta cheese description, properties and shelf life.

Product	Feta cheese
General characteristics	Derived from goat's and sheep's milk (up to 30% goat's milk). It has been ripened. Fat on dry matter approximately 43%, humidity 56% maximum. Does not contain additives
Packaging	Tin cans with brine
Use	Sales to stores
Shelf life	18 months
Instructions for storage and distribution	In the fridge between 0 and 4°C Consumed with no further thermal processing
General specifications	Regulations: 852/2004; 853/2004; 854/2004

of the lactase enzyme preparation at doses of 500, 3000 and 10,000 mg/kg body weight per day for 28 days did not induce noticeable signs of toxicity. The no-observed-adverse-effect level (NOAEL) of the enzyme preparation in the acute toxicity study was 10,000 mg/kg body weight per day (equivalent to 114,000 NL units/kg body weight per day). It can be concluded that no safety concerns were identified in the studies conducted with this lactase enzyme preparation derived from *Kluyveromyces lactis* under controlled fermentation conditions.

3.4 CHEESES

The percentage composition, properties and shelf life of various cheeses are given in Table 3.8 (Feta cheese), Table 3.9 (Telemes), Table 3.10 (Batzos), Table 3.11 (Kasseri), Table 3.12 (semi-hard cheese), Table 3.13 (hard cheese), Table 3.14 (Graviera, Kefalograviera, Kefalotyri), Table 3.15 (Mizithra, Anthotyros, Manouri), Table 3.16 (butter whey), Table 3.17 (hard Italian cheese), Table 3.18 (Cheddar cheese), Table 3.19 (Swiss-type cheese) and Table 3.20 (Camembert cheese).

Table 3.9 Telemes description, properties and shelf life.

Product	Telemes
General characteristics	Derived from cow's, goat's or sheep's milk or their mixtures. It has been ripened. Does not contain additives
Packaging	Tin cans with brine
Use	Sales to stores
Shelf life	18 months
Instructions for storage and distribution	In the fridge between 0 and 4°C Consumed with no further thermal processing
General specifications	Regulations: 852/2004; 853/2004; 854/2004

Table 3.10 Batzos description, properties and shelf life.

Product	Batzos
General characteristics	Derived from goat's and sheep's milk. It has been ripened. Fat on dry matter at least 25%. Humidity 38% maximum. Does not contain additives
Packaging	Tin cans with brine
Use	Sales to stores
Shelf life	18 months
Instructions for storage and distribution	In the fridge between 0 and 4°C Consumed with no further thermal processing
General specifications	Regulations: 852/2004; 853/2004; 854/2004

3.4.1 Feta cheese

Feta is a traditional white soft Greek cheese and representative of the cheeses that are ripened and kept in brine (Abou-Donia, 1991; Anifantakis, 1991a; Tamine and Kirkegaard, 1991). The distinguishing characteristics of Feta are the creamy and rich flavour, the soft texture with some irregular small mechanical openings, the white colour and the rectangular shape (Tsotsanis, 1996; Zerfiridis, 1994).

It is produced from sheep's milk or mixed sheep's and goat's milk in a ratio up to 7:3, respectively (Greek Codex of Foods and Drinks, 1998). Moisture content and minimum fat in dry matter of Feta should be 52–56 and 43%, respectively (Abd El-Salam *et al.*, 1993; Vastardis and Anifantakis, 1992).

Table 3.11 Kasseri description, properties and shelf life.

Product	Kasseri
General characteristics	Derived from sheep's milk. It has been ripened. Fat on dry matter at least 43%. Humidity 56% maximum. No additives
Packaging	Paraffin or vacuum
Use	Sales to stores
Shelf life	18 months
Instructions for storage and distribution	In the fridge between 0 and 4°C Consumed with no further thermal processing
General specifications	Regulations: 852/2004; 853/2004; 854/2004

Table 3.12 Semi-hard cheese description, properties and shelf life.

Product	Semi-hard cheese
General characteristics	Derived from cow's milk. It has been ripened. Minimum fat in dry matter 20–50% (partially skimmed up to excellent quality)/moisture 38–46%. No additives
Packaging	Vacuum in bags
Use	Sales to stores
Shelf life	18 months
Instructions for storage and distribution	In the fridge between 0 and 4°C Consumed with no further thermal processing
General specifications	Regulations: 852/2004; 853/2004; 854/2004

Table 3.13 Hard cheese description, properties and shelf life.

Product	Hard cheese
General characteristics	Derived from cow's milk. It has been ripened. Minimum fat in dry matter 20–47% (partially skimmed up to excellent quality)/moisture 32–38%. No additives
Packaging	Paraffin or vacuum
Use	Sales to stores
Shelf life	18 months
Instructions for storage and distribution	In the fridge between 0 and 4°C Consumed with no further thermal processing
General specifications	Regulations: 852/2004; 853/2004; 854/2004

Table 3.14 Graviera/Kefalograviera/Kefalotyri description, properties and shelf life.

Product	Graviera/Kefalograviera/Kefalotyri
General characteristics	Derived from cow's, goat's or sheep's milk or their mixtures. It has been ripened. Minimum fat in dry matter 40%. Maximum moisture 38%. No additives
Packaging	Paraffin or vacuum
Use	Sales to stores
Shelf life	18 months
Instructions for storage and distribution	In the fridge between 0 and 4°C Consumed with no further thermal processing
General specifications	Regulations: 852/2004; 853/2004; 854/2004

Table 3.15 Mizithra/Anthotyros/Manouri description, properties and shelf life.

Product	Mizithra/Anthotyros/Manouri
General characteristics	Derived from cow's and sheep's whey (Mizithra), goat's and sheep's whey (Anthotyros, Manouri) and from mixing of whey with milk or cream milk. Raw materials have been pasteurised. No ripening. Minimum fat on dry matter 50, 65 and 70% for Mizithra, Anthotyros and Manouri, respectively. Maximum moisture 70%. No additives
Packaging	Vacuum in bags
Use	Sales to stores
Shelf life	3 months
Instructions for storage and distribution	In the fridge between 0 and 4°C Consumed with no further thermal processing
General specifications	Regulations: 852/2004; 853/2004; 854/2004

All stages upstream of cooling of heated milk should comply with the prescribed requirements for pasteurised milk except for a few differences. It should be stressed that the performed controls at the receipt of raw milk are (Mauropoulos and Arvanitoyannis, 1999): (1) acidity, (2) aerobic mesophilic count, (3) freezing point and (4) antibiotic and metabolite residues. The used sheep milk for the production of good-quality Feta should have lower acidity than 0.23% and pH higher than 6.55 (Anifantakis, 1991b). Sheep milk should also be standardised to a fat and casein content of 5.8 and 4.6%, respectively (Greek Codex of Foods and Drinks, 1998). The lactic cultures used for Feta are *Lactobacillus bulgaricus–Streptococcus thermophilus* (1:1) (Pappas and Zerfiridis, 1989), *Lactobacillus bulgaricus–Lactococcus*

Table 3.16 Butter whey description, properties and shelf life.

Product	Butter whey
General characteristics	Derived from pasteurised whey cream, maximum moisture 18%, no additives
Packaging	Tin cans
Use	Sales to stores
Shelf life	12 months
Instructions for storage and distribution	In the fridge between 0 and 4°C Consumed with no further thermal processing
General specifications	Regulations: 852/2004; 853/2004; 854/2004

Table 3.17 Hard Italian cheeses description, properties and shelf life.

Product	Hard Italian cheeses (Provolone, Romano and Parmesan)
General characteristics	Provolone: moisture <45% and fat in dry matter 46–47%, Romano: moisture <34% and fat in dry matter >38% and Parmesan: moisture <32% and fat in dry matter >32%. Provolone and Romano cheeses are manufactured from either raw or HTST pasteurised standardised milk, while Parmesan cheese is produced only from HTST pasteurised standardised milk
Packaging	Vacuum or different types of wax
Use	Sales to stores
Shelf life	6 months
Instructions for storage and distribution	In the fridge between 0 and 4°C Consumed with no further thermal processing
General specifications	Regulations: 852/2004; 853/2004; 854/2004

lactis (3:1) and *Lactobacillus casei–Lactococcus lactis* (1:1) (Abd El-Salam *et al*., 1993). Starter culture should be inoculated at 1% and should be left at 32–34°C for 15–30 minutes (milk ripening). The activity of the lactic culture should be verified by monitoring the acidity development in milk. Contamination with bacteriophages can alter the activity of the culture, while phage inhibitory media for starter growth can be used to minimise the hazard of bacteriophages (Cogan and Hill, 1993). The acidity of milk should be measured in order to control the quantity of rennet and the temperature of milk before rennet addition (Mehanna *et al*., 1998).

Table 3.18 Cheddar cheese description, properties and shelf life.

Product	Cheddar cheese
General characteristics	Cheddar cheese has moisture content lower than 39% and fat –in –dry matter higher than 50%. Cheddar cheese is manufactured from pasteurised milk. The pH value of the fresh product should be 5.2–5.3
Packaging	Vacuum or wax
Use	Sales to stores
Shelf life	4 months
Instructions for storage and distribution	In the fridge between 0 and 4°C Consumed with no further thermal processing
General specifications	Regulations: 852/2004; 853/2004; 854/2004

Table 3.19 Swiss-type cheese description, properties and shelf life.

Product	Swiss-type cheese (Gruyère and Emmental)
General characteristics	Gruyère: moisture 38% and fat in dry matter 49% and Emmental: moisture 40% and fat in dry matter 45%. The characteristic eye formation in these cheeses is related to propionic acid fermentation and to CO_2 release. Raw milk used for these cheeses should be a premium microbiological quality
Packaging	Vacuum and in Emmental wax
Use	Sales to stores
Shelf life	3 months
Instructions for storage and distribution	In the fridge between 0 and 4°C Consumed with no further thermal processing
General specifications	Regulations: 852/2004; 853/2004; 854/2004

Many European cheeses are characterised by complex bacterial surface flora. This so-called 'red smear' consists of yeasts, coryneform bacteria and (micro-/) staphylococci (Kammerlehner, 1995). The smear layer protects cheeses from drying and contaminations with undesirable bacteria and moulds. The composition of the surface flora depends largely on the specific house microflora of the cheese manufacturer.

Traditionally, growth of the surface microflora is initiated with the help of mature cheeses, which release part of their surface microflora into the smear tank. Thus, all necessary micro-organisms have been transferred to the smear tank, from where smearing

Table 3.20 Camembert cheese description, properties and shelf life.

Product	Camembert cheese
General characteristics	The typical composition of Camembert cheese found commercially is 50% moisture content, 28% fat content, and 2% salt and minerals
Packaging	Different types of wax or vacuum
Use	Sales to stores
Shelf life	6 months
Instructions for storage and distribution	In the fridge between 0 and 4°C Consumed with no further thermal processing
General specifications	Regulations: 852/2004; 853/2004; 854/2004

of young cheeses is started (old–young smearing). Although this process is rather inexpensive, the disadvantage is that pathogens (e.g. *Listeria monocytogenes*) or other contaminants like moulds are also transferred to the smear/spray tank and are spread to all cheeses in the factory (Bockelmann *et al*., 1997). Apart from *Listeria*, enterobacteria with transferable antibiotic resistances are matters of concern in this respect as well (Teuber, 1999).

Since the microbial ecology of smear cheese surfaces is still not understood in detail, no surface ripening cultures of adequate composition are commercially available. However, such cultures will be necessary for cheese factories (often small and medium enterprises) to meet the continuously increasing hygienic demands of European guidelines and regulations. Generally, only a few species like *Debaryomyces hansenii* and *Brevibacterium linens* are used as smear adjuncts, which do not reflect the microbial complexity found on the surface of smear cheeses.

Bockelmann (2002) reported on growth on cheese (lab scale) of the five strain minimal starter developed comparable to that of a typical old–young smear 'starter'. A complete smear layer was developed within 4–7 days. It consisted of the yeast *Debaryomyces hansenii*, and the bacteria *Brevibacterium linens*, *Arthrobacter nicotianae*, *Corynebacterium ammoniagenes* and *Staphylococcus equorum*. When defined starters were tested on a pilot scale, a too weak sulphury volatile flavour was observed compared to the old–young smeared control cheeses. Some of the key sulphur components (methanethiol and derivatives), some alcohols and aldehydes were produced at lower levels by the defined starters. The development of typical light-brown cheese colour (so-called 'red smear') was attributed to the interactions between yellow-pigmented *Arthrobacter* spp. and proteolytic bacteria. The orange pigments of *B. linens* and staphylococci were found to be of lesser importance. The role of *Corynebacterium* species which show fast growth is still not clear. An impact of this predominant part of the smear flora on aroma and colour development can be expected. However, clear effects were not observed in experiments with model systems.

It has been reported that high pressure (HP) (pressures between 300 and 600 MPa) improves rennet or acid coagulation of milk without detrimental effects on important quality characteristics, such as taste, flavour, vitamins and nutrients (Trujillo *et al*., 2002). These characteristics offer the dairy industry numerous practical applications to produce microbiologically safe, minimally processed dairy products with improved performances, and to develop novel dairy products of high nutritional and sensory quality, novel texture and increased shelf life. It is also well known that HP applications on milk and dairy products have shown to be an effective method to inactivate micro-organisms including most infectious foodborne pathogens.

In milk, HP produces casein micelles disintegration into casein particles of smaller diameter, with a decrease in milk turbidity and lightness, and an increase of viscosity of the milk (Johnston *et al*., 1992). Furthermore, the pressure-induced dissociation of the colloidal calcium phosphate and denaturation of serum proteins in milk may change and/or improve its technological properties (Lopez Fandino *et al*., 1996).

Dry-salting of Feta requires the use of corn-sized granular salt, which is slowly dissolved and contributes to the drainage of the curd (Anifantakis, 1991a, b). Salt should be evenly distributed in the mass of cheese. Within the first 24 hours, salt-in-moisture should be 2.5% and pH 5.2 to ensure the safe preservation and normal ripening of Feta (Mehanna *et al*., 1998; Pappas *et al*., 1996). During salting, Feta should also be protected from flies because they lay their eggs on the cheese surface causing its spoilage within a few days (Zerfiridis, 1994). Further ripening is completed at 5°C after two months (Tsotsanis, 1996). Ripening usually lasts for two weeks at 16°C and 85% relative humidity and is crucial to the development of the characteristic physicochemical and organoleptic properties of Feta. Ripening rooms should be separated from the rest of the plant, be equipped with an air filtration system and thoroughly cleaned (Mauropoulos and Arvanitoyannis, 1999). By the end of the first ripening stage, the pH should be 4.0–4.6 because lower values result in moisture loss, acidic taste and limited compactness, while higher values lead to reduced shelf life (Anifantakis, 1991a).

After milking, the raw milk is chilled to below 4°C and kept at this temperature during its transportation to the dairy factory. Following reception, milk is filtered and stored in large silo tanks and is sampled for analyses. The milk is standardised (casein/fat 0.7–0.8), pasteurised (72°C/15 seconds) and cooled down to 32°C. At this temperature, a starter culture is added and after 30 minutes, rennet is also added and the milk is coagulated in 50–60 minutes. The coagulum is cut by using a 2-cm wire knife; it stays for ten minutes and is then transferred in thin layers into perforated moulds. The moulds are rectangular of dimensions $23 \times 23 \times 35$ mm^3. The curd is drained without pressing, until it is firm enough to remove the moulds. The cheese is cut into four blocks of $11 \times 11 \times 8$ cm^3. These blocks are dry-salted on the surface. After 12 hours, the blocks are reversed and salted again. This is repeated until the salt content of cheese reaches 4%. After the cheese blocks have thus remained on the cheese tables for a

few more days, the cheeses are packed into tin cans, containing 6–8% salt solution and kept at 14–16°C for about 15 days until they attain pH 4.6 and moisture content 55%. The cheeses are then transferred to new containers where more brine is added and the containers are sealed and stored at 4°C (Mauropoulos and Arvanitoyannis, 1999).

Packaging of Feta is traditionally carried out in barrels, although nowadays tins are mostly used. Tins are filled with 6% brine to cover the surface of the cheese, are hermetically sealed, and transferred to the refrigerator. Other types of conventional wrapping for soft cheeses can consist of waxed paper board (both sides)/regenerated cellulose or high-density polyethylene (HDPE) or polyethylene terephthalate (PET) coated with hydrosorbent coating (Mathlouthi *et al.*, 1994). Feta should not be packaged and cooled unless it has reached a pH value of at least 4.6, otherwise the cheese will convert into a soft, creamy mass similar to mud. Moreover, the destruction of pathogens, such as *coliforms*, *Salmonella* and *Brucella* is not feasible during ripening. Killing of *Mycobacterium* requires adequate pasteurisation of milk and is not affected by pH value or salt concentration in cheese (Hammer *et al.*, 1998). In the refrigerator, tins can swell if temperature exceeds 5°C or psychrotrophs continue cheese fermentation. To prevent tin swelling, the temperature should be constantly monitored and a small, easily covered hole should be made at the surface of the tins to release the produced gases. The relative humidity in the refrigerator should also be controlled to prevent tin rusting. Feta is safe for consumption only after 2 months ripening at 5°C (Sandrou and Arvanitoyannis, 2000a).

3.4.2 Teleme and Mizithra cheeses

Teleme cheese is a soft white cheese, ripened and kept in brine. The technology of this cheese was first introduced in Greece by refugees who came from Romania and was quickly spread, because it was easier than the technology for Feta cheese. Teleme cheese is made only from cow's milk, is salted directly into brine, lacks the characteristic slime that develops on the surface of Feta cheese, and is packaged into tins. The distinguishing characteristics of Teleme cheese are the piquant flavour, the white yellowish colour and the hard and friable texture. Its usual composition is less than 70% moisture content and less than 10% fat content and it is widely preferred for its low-fat content (Sandrou and Arvanitoyannis, 2000a).

Mizithra cheese can be made from both cow's and sheep's whey used for the manufacture of Teleme or Feta cheese and is characterised by the presence of whey proteins, which have higher nutritional value than the caseins contained in the cheese curd. The composition of Mizithra cheese from cow's whey is 70% moisture content and 11% fat content, while the composition of low-fat Mizithra cheese is $80 \pm 2.8\%$ moisture content and $1.4 \pm 0.9\%$ fat content.

Raw milk should comply with the prescribed requirements for the safety of raw milk used for Feta cheese. Milk should be standardised to 3% fat content by means of a separator to meet the legal requirements for the composition of Teleme cheese.

Lactic culture of *Streptococcus lactis* and *Lactobacillus bulgaricus* (1:3) should be added at 0.5% and left at 32°C for 35 minutes to lower the pH value to 6.5 (milk ripening). Unsuccessful milk ripening reveals that the lactic culture is inactive and requires an additional quantity of the starter in order to avoid growth of undesirable micro-organisms and degraded organoleptic characteristics. Rennet should be added at the appropriate proportion, depending on the temperature and acidity of the milk. If cheese milk was stored for an extended time and has high acidity, the rennet quantity should increase, while milk temperature should be lower than 32°C to complete curd formation rapidly and to prevent the growth of any undesirable microflora. At this stage, $CaCl_2$ should be added to compensate for Ca^{2+} losses during pasteurisation, while chlorophyll should be added to change the yellowish colour of cow's milk into white. When the curd formation is completed, the coagulum should be cut to avoid excessive fat losses. Curd pieces should be uniform and of proper size to ensure adequate moisture expulsion. Then, the curd should be transferred into moulds to drain and the next day the pH value of the curd should be 4.8–4.9. Insufficient acidity development is detrimental to Teleme cheese quality, because it can lead to growth of *E. coli* and gas formation by coliforms (Sandrou and Arvanitoyannis, 2000a).

Teleme cheese should be salted into brine of 18°Bé and at 16°C, while its surface should be dry-salted with high-grade salt. The following morning, the cheese temperature should be 20°C, the pH value should be lower than 5.2, the moisture content should be 65% and the salt concentration should be higher than 2.5%. After two days, the cheese should be dry-salted, transferred into sealed tins and left for 2 weeks to ripen. At the beginning of ripening (16°C), the pH value should be 4.8, the salt concentration should be higher than 3% and the moisture content should be 57%. Ripening is crucial to the destruction of pathogens and contamination with coliforms and yeasts should be avoided to prevent blowing of Teleme cheese. When the salt concentration has reached 5%, the moisture content is 54% and the pH value is lower than 4.8, the tins should be placed into the refrigerator at 4–5°C for

2 months to complete cheese ripening (Arvanitoyannis and Mavropoulos, 2000).

The whey removed during Teleme cheese production can be successfully used for the production of Mizithra cheese. The characteristics of the whey should be a pH value of 6.38 and acidity of 9–11°D (degree Dornic), a fat content of 0.3–0.4%, and a temperature of 32–35°C. Low acidity of the whey permits the denaturation and coagulation of whey proteins and increases cheese yield. Whey should be heated at 88–90°C for 5–7 minutes and the pH value should be adjusted to the isoelectric point of the whey proteins. The temperature should rise progressively (1–1.5°C/minute) and heating should be completed within 45–50 minutes. The optimum pH value varies within the range 5.5–5.8 and depends on the physicochemical condition of the whey and on the calcium concentration. The pH adjustment is usually done with a solution of citric acid and the protein coagulum formed is collected and placed into moulds, where the temperature decreases progressively. Since, after heating, there are few competitive microflora, the danger of undesirable fermentations caused by coliforms and yeasts is high. A combination of dry-salting and the use of proper cultures can contribute to a sufficient decrease in pH value and to the development of better organoleptic characteristics. Finally, Mizithra cheese is packaged into tins and can be safely kept in refrigerators for 3–4 months.

Mizithra, Anthotyros and Manouri are whey cheeses traditionally produced in Greece from whey derived from cheeses made from mixtures of ewe's and goat's milk. Whey from Feta cheese is mostly used for preparation of these whey cheeses. Govaris *et al.* (2001) studied the behaviour of *E. coli* O157:H7 in Mizithra, Anthotyros and Manouri whey cheeses. Results showed that *E. coli* O157:H7 can grow at 12°C and survive at 2°C storage in Mizithra, Anthotyros and Manouri whey cheeses, and therefore post-manufacturing contamination with this pathogen must be avoided by employing hygienic control programmes such as HACCP accompanied by good manufacturing practices (GMPs).

The determination of CCPs and the flow diagram for Feta cheese, Batzos and Telemes are given in Table 3.21 and Fig. 3.2, respectively.

3.4.3 Kasseri cheese

Kashkaval is a typical Balkan pasta filata cheese, which is traditionally made from sheep's milk (Robinson, 1995). Its Greek relative is Kasseri cheese, which is very popular in Greece. Since 1996, Kasseri belongs to the products with 'protected name of origin' in the EU (Regulation 1017/1996/EU). Kasseri cheese is produced from sheep's milk or from a mixture of sheep's and up to 20% goat's milk. The addition of goat's milk leads to harder cheeses. The major advantage of this cheese is that it can be produced from milk with high acidity (Zerfiridis, 1997). The annual manufacture in Greece is approximately 21,000 tonnes (Zerfiridis, 1994).

The typical form of Kasseri cheese is flat, cylindrical and its typical size is : diameter, 25–30 cm; height, 7–10 cm; and weight, 7–8 kg. Its texture is firm and the few holes, if any, are uniformly distributed. The cheese has a white-yellow colour and a rind of the same colour. It is packaged in Cryovac plastic bags, at the age of three weeks, and its ripening time is of duration of at least three months. The cheese is distinguished for its pleasant taste and flavour and is consumed as table cheese or used for pizza production like Mozzarella cheese (Rudan and Barbano, 1998). Kasseri is a semi-hard cheese with maximum moisture 40% and minimum fat –in –dry matter 40%. The determination of CCPs and the flow diagram for Kasseri and semi-hard cheese are given in Table 3.22 and Fig. 3.3, respectively.

3.4.4 Kefalotyri cheese

Kefalotyri is a traditional Greek cheese made from sheep's or goat's milk or a mixture of them (Anifantakis, 1991b). Since 1996, Kefalotyri is of 'protected name of origin' in the EU (Regulation (EC) No. 1017/1996). The name is supposed to refer to the 'head-shaped' appearance of the cheese (Kalantzopoulos, 1993). Around 3600 tonnes of Kefalotyri cheese are annually consumed in Greece (Zerfiridis, 1994). The main characteristics of Kefalotyri cheese are its hard texture, salty taste and strong flavour. It is a hard rind cheese of white-yellow colour. Small gas holes and bigger slit holes exist in the mass of cheese. Kefalotyri has a flat cylindrical shape, diameter of 32–34 cm, height of 12–14 cm and weight of 8–10 kg. The chemical constituents of the final product are: moisture 36%, fat 28%, fat –in –dry matter 45%, pH 5.6 and salt content 4%.

The thermophilic starters used consist of *Str. thermophilus* and *Lb. bulgaricus* (2:1) (Robinson, 1995), or *Str. thermophilus* and *Lb. casei* (8:2) (Pappas and Zerfiridis, 1989), or *Str. thermophilus*, *Str. diacetylactis* and *Str. durans* (4:4:2) (Tzanetaki, 1993). After dry-salting, the cheeses are waxed or coated with plastic films and curing continues for three months at 15°C. Cured cheeses are stored at 4–5°C, thereafter. Ripening for 3 months makes a cheese ready for consumption. Kefalotyri is consumed as table or grated cheese. The determination of CCPs and the flow diagram for

Table 3.21 Determination of critical control points (CCPs) for Feta cheese/Batzos/Telemes.

S/n	Processing step	Hazard	Description of hazards	Q1	Preventive action	Q2	Q3	Q4	α/α CCP
1	Water	Biological	Polluted water with high microbial load and other chemical substances	Yes	Annual microbiological and chemical control	No	Yes	No	
		Chemical		Yes	Monthly routine control	No	Yes	No	
3	Milk receipt	Biological	Milk with high microbial load	Yes	Periodical control of milk sample	No	Yes	Yes	**CCP 1a**
				Yes	Determination of pH	Yes			**1b**
			Distribution under non-hygienic conditions	Yes	Control of temperature of receipt and cleaning of the vehicle	Yes			
		Physical	Foreign matter, hair and other material	Yes	Filtration, macroscopic control	No	Yes	Yes	**1c**
		Chemical	Antibiotics, pesticide residues		Periodical control of milk for antibiotic residues	No	Yes	No	**1d**
			Adulterated milk (with water or cheaper milk)	Yes	Determination of specific gravity Instructions to producers and sign of agreements for standard specifications (TPC, somatic cells, antibiotics, fat concentration)	Yes			
2, 4, 5	Receipt of other raw materials Salt	Biological	Contaminated raw materials, Use after expiry date	Yes	Reliable suppliers, raw materials' specifications according to legislation Implementation of FIFO	No	Yes	Yes	
	Starter cultures	Physical	Presence of foreign matter	Yes	Macroscopic control before use	No	Yes	Yes	
	Rennet	Chemical	Presence of heavy metals	Yes	Reliable suppliers, raw materials' specifications according to legislation	No	No		
6, 9	Receipt–storage of packaging materials	Biological	Presence of contaminants and foreign matter	Yes	Macroscopic control. Ideal storage conditions/cleaning	No	Yes	Yes	
		Physical	Moisture uptake	Yes	Conformity certificates for the use of packaging materials in the food industry	No	Yes	Yes	
		Chemical	Packaging materials non-conforming to come into contact with food	Yes		No	No		
7	Pasteurisation	Biological	Survival of pathogenic micro-organisms, weakness of satisfactory reduction of the initial microbial load	Yes	Control of time and temperature of pasteurisation	No	Yes	Yes	
8	Starter culture preparation	Biological	Lower quantity of culture	Yes	Use according to suppliers' instructions	No	No		
			Weak culture	Yes	Use before expiry date	No	No		

(*Continues*)

Table 3.21 (Continued)

S/n	Processing step	Hazard	Description of hazards	Q1	Preventive action	Q2	Q3	Q4	α/α CCP
10	Brine formation	Biological	Weak brine, weakness of antimicrobial action	Yes	Determination of Baumé degrees	Yes			**CCP2**
11	Curd formation	Biological	Weakness of fast multiplication of good micro-organisms, prevailing of undesirable and harmful ones	Yes	Weigh rennet Monitoring of temperature of cheese boiler Monitoring of curdling time Control of milk temperature	Yes			**CCP3**
12–19	Curd cut–moulding	Biological/ physical	Contamination from equipment and personnel. Uneven pieces. Uneven draining	Yes	Regular cleaning and disinfection, GMPs	No	Yes	Yes	**CCP4**
20, 21	Dry-salting/ ripening in cheese tables and in open containers	Biological	Lowering of pH and removal of moisture Early stop of ripening	Yes	pH monitoring Temperature control and check of ripening area Macroscopic control	Yes			**CCP5**
22	Cooling	Biological	Growth of micro-organisms	Yes	Temperature control of cooling chambers	Yes			**CCP6**
			Release before the end of ripening	Yes	Control of pH, production dates				
23	Distribution	Biological	Growth of undesirable micro-organisms	Yes	Control of temperature of vehicles	Yes			**CCP7**

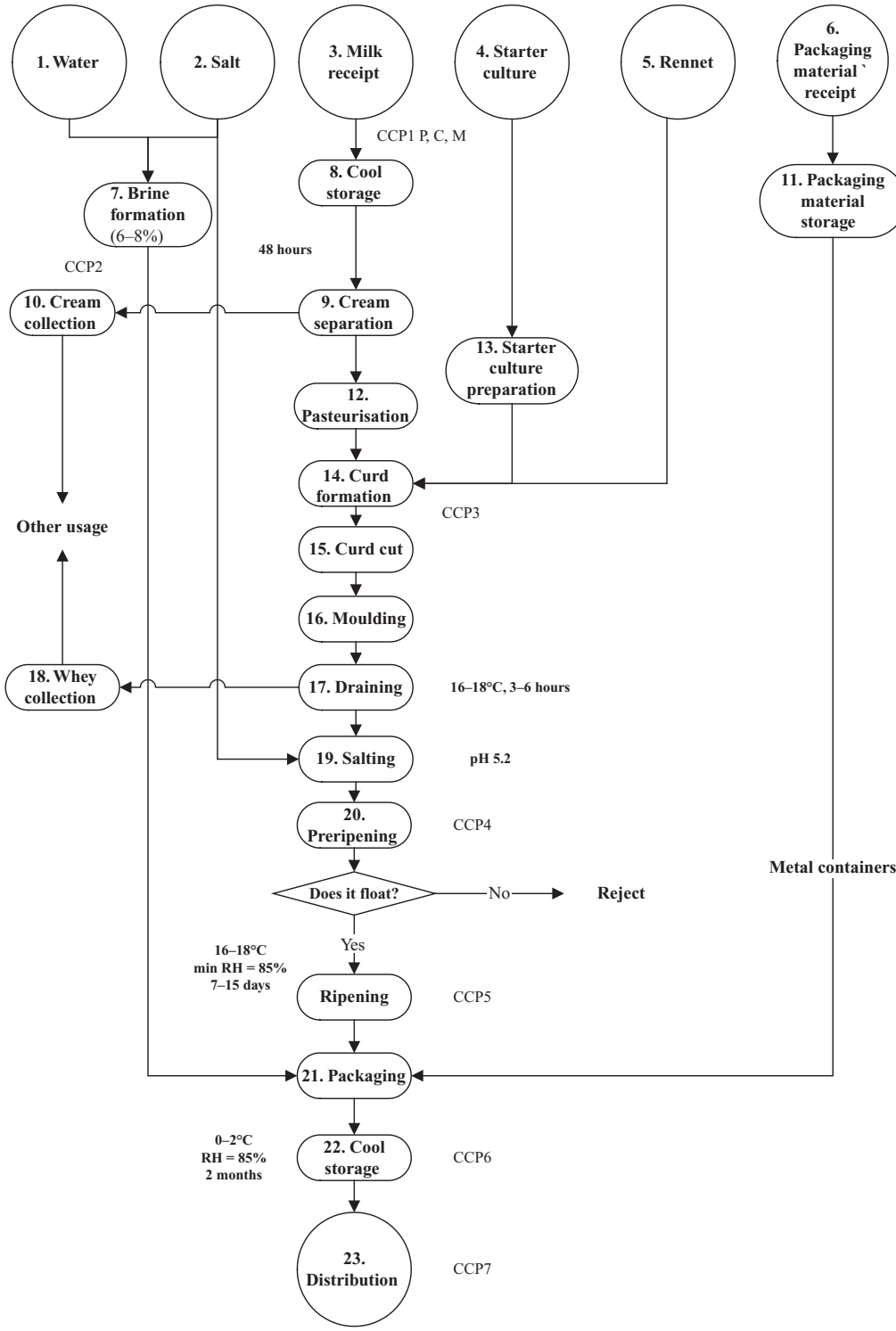

Fig. 3.2 Feta cheese/Batzos/Telemes flow diagram production.

Table 3.22 Determination of critical control points (CCPs) for Kasseri/semi-hard cheese.

S/n	Processing step	Hazard	Description of hazards	Q1	Preventive action	Q2	Q3	Q4	α/α CCP
1	Water	Biological	Polluted water with high microbial load and other chemical substances	Yes	Annual microbiological and chemical control	No	Yes	No	*SSM1*
		Chemical		Yes	Monthly routine control	No	Yes	No	
3	Milk receipt	Biological	Milk with high microbial load	Yes	Periodical control of milk sample	No	Yes	Yes	**1a**
					Determination of pH	Yes	Yes	Yes	**1b**
			Distribution under non-hygienic conditions	Yes	Control of temperature of receipt and cleaning of the vehicle	Yes No	Yes	No	**1c** **1d**
		Physical	Foreign matter, hair and other material	Yes	Filtration, macroscopic control	No Yes			
		Chemical	Antibiotics, pesticide residues	Yes	Periodical control of milk for antibiotic residues				
			Adulterated milk (with water or cheaper milk)	Yes	Determination of specific gravity Instructions to producers and sign of agreements for standard specifications (TPC, somatic cells, antibiotics, fat concentration)				
2, 4, 5	Receipt of other raw materials Salt Starter cultures Calcium chloride	Biological	Contaminated raw materials, Use after expiry date	Yes	Reliable suppliers, raw materials' specifications according to legislation Implementation of FIFO	No No No	Yes Yes No	Yes Yes	
		Physical	Presence of foreign matter	Yes	Macroscopic control before use				
		Chemical	Presence of heavy metals	Yes	Reliable suppliers, raw materials' specifications according to legislation				
6	Receipt–storage of packaging materials	Biological	Presence of contaminants and foreign matter	Yes Yes	Macroscopic control. Ideal storage conditions/cleaning	No No	Yes Yes	Yes Yes	
		Physical	Moisture uptake	Yes	Conformity certificates for the use of packaging materials in the food industry	No	No		
		Chemical	Packaging materials non-conforming to come into contact with food						
9	Pasteurisation	Biological	Survival of pathogenic micro-organisms, weakness of satisfactory reduction of the initial microbial load	Yes	Control of time and temperature of pasteurisation	No	Yes	Yes	
12	Curd formation	Biological	Weak growth of good micro-organisms, prevailing of undesirable and harmful ones	Yes	Weigh rennet Monitoring of temperature of cheese boiler Monitoring of curdling time Control of milk temperature	Yes			**CCP2**
13, 18	Curd cut–moulding	Biological/ physical	Contamination from equipment and personnel. Uneven pieces. Uneven draining	Yes	Regular cleaning and disinfection, GMPs	No	Yes	Yes	**SSM2**

14	Stirring/ reheating/ precipitation	Biological/ physical	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No	Yes	Yes	
15	Curd removal/ curd extraction	Biological/ physical	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No	Yes	Yes	
16	Cutting/ mixing	Biological/ physical	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No	Yes	Yes	
17	Pressing of cheese mass	Biological/ physical	Contamination from equipment and personnel Unable to remove the required quantity of whey	Yes Yes	Regular cleaning and disinfection, GMPs. Use of appropriate weights, adjustment of room temperature	No No	Yes No	Yes	
21	Ripening of cheese mass	Biological	Failure of prevailing of good micro-organisms and drop of pH	Yes	Adjustment of temperature and humidity, filtering test, control of pH	No	Yes	Yes	
	Cutting/ immersion in hot water/ fermentation	Biological/ physical Biological	Clotted, unstrained kasseri mass Contamination from equipment and personnel Failure to kill micro-organisms	Yes Yes	GMPs, regular cleaning and disinfection, Time and temperature control	No Yes	Yes	Yes	**CCP3**
	Moulding/ hardening of cheese heads	Biological/ physical	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No	Yes	Yes	
20	Mould removal	Biological/ physical	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No	Yes	Yes	
	Salting/ ripening	Biological	Failure to remove moisture Growth of undesirable micro-organisms	Yes	Regular salting Temperature control and adjustment of moisture in the chamber of ripening	Yes			**CCP4**
	Drying	Biological	Moisture points on the surface of the cheese, mould growth	Yes	Macroscopic control before packaging	No	No		
22	Paraffin/ packaging	Biological/ physical	Contamination from equipment and personnel						
23	Cooling	Biological	Growth of micro-organisms Release before the end of ripening	Yes Yes	Temperature control of cooling chambers Control of pH, production dates	Yes			**CCP5**
	Distribution	Biological	Growth of undesirable micro-organisms	Yes	Control of temperature of vehicles	Yes			**CCP6**

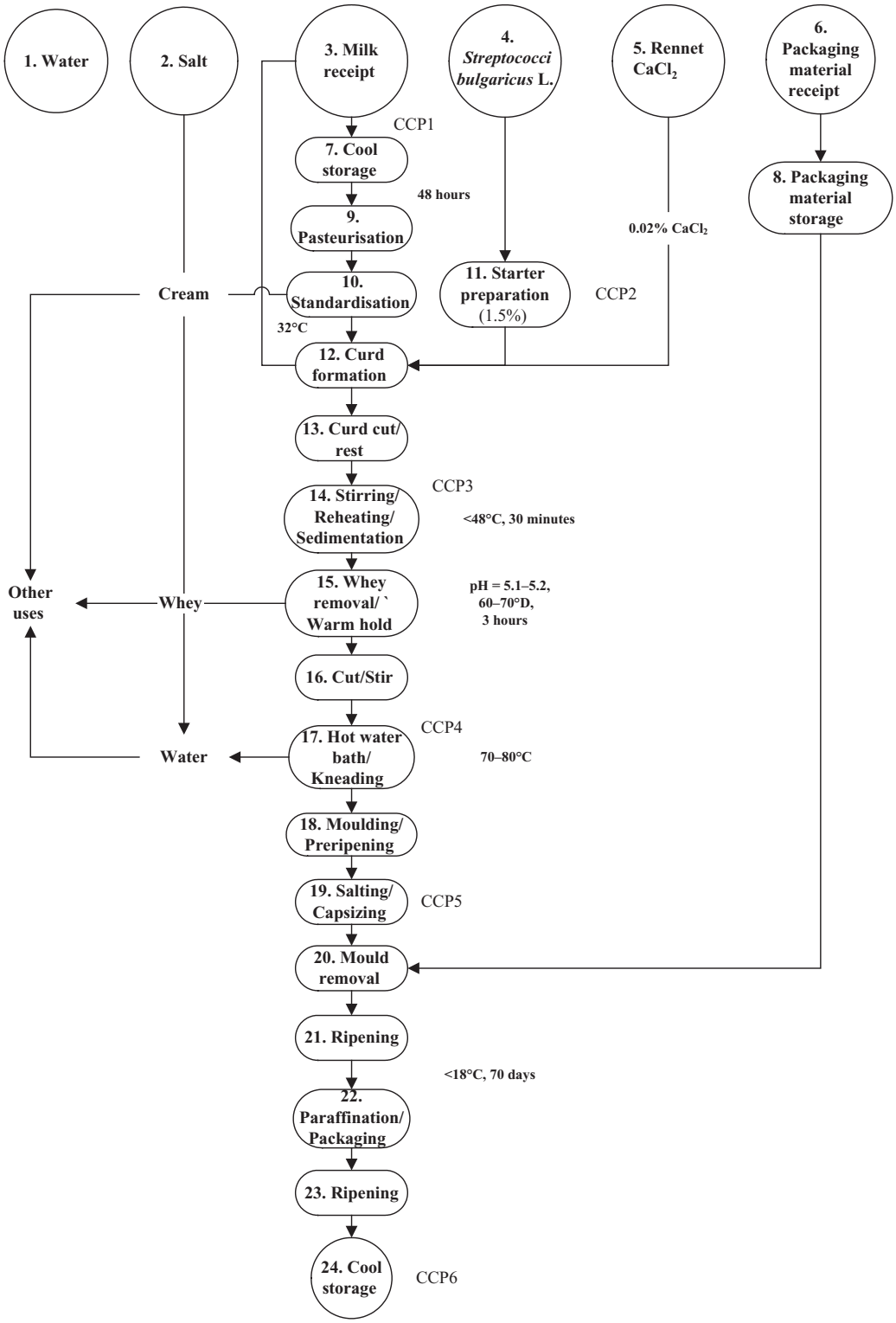

Fig. 3.3 Kasseri/semi-hard cheese flow diagram.

Graviera, hard cheese and Kefalotyri are given in Table 3.23 and Fig. 3.4, respectively.

3.5 CCPs IN THE PRODUCTION LINE OF KASSERI AND KEFALOTYRI

3.5.1 Storage in silo tanks

The raw milk should be cooled down to temperatures below 6°C (Directive 92/46/EEC). Silo tanks must be provided with a stirring system for the uniform cooling of milk. Mixing stored raw milk with recently received raw milk should be discouraged. To avoid the risk of further growth of micro-organisms potentially dangerous to human health (e.g. *Bacillus cereus*), milk should be kept at the lowest possible temperature (e.g. 4°C) and treated within 72 hours. Milk to be stored for longer periods is usually subjected to a mild heat treatment ('thermisation') (van den Berg, 1984). Daily cleaning schedules for the silo tanks should be set up, documented and updated.

3.5.2 Pasteurisation

The pasteurisation process is carried as a continuous operation with the milk heated in a heat exchanger and then held in a holding tube for a prescribed time. In an HTST (high-temperature short time) system, the minimum temperature–time conditions are 72°C for 15 seconds. The heat treatment aims at limiting public health hazards arising from pathogenic micro-organisms (e.g. *Coxiella burnetii*) associated with milk (Jervis, 1992).

Moreover, HTST extends the quality of cheese by reducing the number of spoilage micro-organisms. After heat treatment, milk gives a negative phosphatase test. The surviving micro-organisms are thermoresistant (Micrococcus, Streptococcus, Lactobacillus), surviving without any further growth, and thermophilic bacteria (Micrococcus, Coryneform), able to survive and grow (Hull *et al*., 1992). Although not all of them are pathogens, a critical limit should be established.

Pasteurisation equipment should be properly designed and meticulously operated to ensure that the entire amount of milk is heated to the appropriate temperature and that the flow diversion valve (leading to repasteurisation) is properly operated. The holding tube should be of uniform diameter and the holding time must be very accurately determined. Preventative measures include an automatic safety system to prevent too low or too high temperatures, extra cleaning if more than three days have elapsed between processing runs and inspection of appropriate removal of salt residues. The pressure difference between pasteurised and untreated milk should be tested and calibrated at 0.5 bar, to avoid the cross-contamination of pasteurised milk (Dijkers *et al*., 1995). Thorough records of pasteurisation temperatures, deviations and undertaken corrective actions should be kept.

Pasteurisation constitutes a CCP, because some pathogens and bacteria such as Mycobacterium can survive under the ripening conditions (pH, % NaCl) and is of high risk for public health (Hammer *et al*., 1998). At least one CCP must proceed pasteurisation (e.g. reception of raw milk), because bacterial agglomerations, toxins and spores are not easily destroyed and antibiotics, aflatoxins or other chemical substances cannot be eliminated with pasteurisation.

Cross-contamination of milk after pasteurisation is of major importance and has to be avoided for producing cheeses that are both safe and of desirable storage life (Varnam and Sutherland, 1996). The main contamination sources are: air, water, equipment, people, utensils, starter cultures, rennet and packaging. The most common micro-organisms contaminating the product after pasteurisation are: *Staphylococcus*, *Salmonella*, *Campylobacter*, coliforms and *Yersinia*. The presence of *E. coli* indicates potential contamination with pathogenic micro-organisms which may grow at ripening conditions of cheese with potential problems for public health.

Faeces are the primary source of pathogenic *E. coli* contamination of agricultural commodities and, as there is no definitive assay for faecal contamination, FDA (1995) and FSIS (1990) use the presence of generic *E. coli* as an indicator for faecal contamination. The adverse health risks of *E. coli* in foods are well documented (Armstrong *et al*., 1996; Hui, 2001; Mead *et al*., 1999). Faeces can also be the source of many other types of pathogenic organisms, including parasites (Blackburn and McClure, 2002; Hui, 2001). The authors have demonstrated that fluorescence can be a very sensitive method for detecting faeces (Kim *et al*., 2002, 2003; Lefcourt *et al*., 2003), and that fluorescence responses of faeces from different animal species are similar. Lefcourt *et al*. (2005) describe a transportable imaging system for detecting faecal contamination. The primary components of the system are a UV light source, an intensified camera with a six-position filter wheel, and software for controlling the system and automatically analysing images.

Cleaning and disinfection procedures of the heating equipment are optimised and programmed. Duration, temperature and concentration of the cleaning solution are checked and records are kept.

Table 3.23 Determination of critical control points (CCPs) for Graviera/hard cheese/Kefalotyri

S/n	Processing step	Hazard	Description of hazards	Q1	Preventive action	Q2	Q3	Q4	α/α CCP
1	Water	Biological	Polluted water with high microbial load and other chemical substances	Yes	Annual microbiological and chemical control	No	Yes	No	
		Chemical		Yes	Monthly routine control	No	Yes	No	**CCP 1a**
3	Milk receipt	Biological	Milk with high microbial load	Yes	Periodical control of milk sample	No	Yes	Yes	**1b**
				Yes	Determination of pH	Yes	Yes	Yes	**1c**
			Distribution under non-hygienic conditions	Yes	Control of temperature of receipt and cleaning of the vehicle	Yes No	Yes	No	**1d**
		Physical	Foreign matter, hair and other material	Yes	Filtration, macroscopic control	No			
				Yes	Periodical control of milk for antibiotic residues	Yes			
		Chemical	Antibiotics, pesticide residues						
			Adulterated milk (with water or cheaper milk)		Determination of specific gravity Instructions to producers and sign of agreements for standard specifications (TPC, somatic cells, antibiotics, fat concentration)				
2, 4, 5	Receipt of other raw materials Salt	Biological	Contaminated raw materials Use after expiry date	Yes	Reliable suppliers, raw materials conforming to the legislation Implementation of FIFO	No	Yes	Yes	
	Rennet	Physical	Presence of foreign matter	Yes	Macroscopic control before use	No	Yes	Yes	
		Chemical	Presence of heavy metals	Yes	Reliable suppliers, raw materials conforming to the legislation	No	No		
6	Receipt–storage of packaging materials	Biological	Presence of contaminants and	Yes	Macroscopic control. Ideal storage	No	Yes	Yes	
		Physical	foreign matter	Yes	conditions/cleaning	No	Yes	Yes	
		Chemical	Moisture uptake Packaging materials non-conforming to come into contact with food	Yes	Conformity certificates for the use of packaging materials in the food industry	No	No		
	Brine formation	Biological	Weak brine, weakness of antimicrobial action	Yes	Determination of Baumé degrees	Yes			**CCP2**
10	Pasteurisation	Biological	Survival of pathogenic micro-organisms, weakness of satisfactory reduction of the initial microbial load	Yes	Control of time and temperature of pasteurisation	No	Yes	Yes	
12	Curd formation	Biological	Slow growth of "good" micro-organisms, prevailing of undesirable and harmful ones	Yes	Weigh rennet Monitoring of temperature of cheese boiler Monitoring of curdling time Control of milk temperature	Yes			**CCP3**
13	Curd cut–moulding	Biological/ physical	Contamination from equipment and personnel. Uneven pieces. Uneven draining	Yes	Regular cleaning and disinfection, GMPs	No	Yes	Yes	

14	Stirring/ reheating/ precipitation	Biological/ physical	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No	Yes	Yes	**SSM2** **SSM3**
15	Curd removal/ curd extraction	Biological/ physical	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No	Yes	Yes	**SSM2** **SSM3**
16	Moulding	Biological/ physical	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No	Yes	Yes	**SSM2** **SSM3**
17	Pressing/ change of paddy/ reversing	Biological/ physical Biological	Contamination from equipment and personnel Inability to remove moisture, prevailing of good micro-organisms	Yes Yes	Regular cleaning and disinfection, GMPs Control of room temperature conditions Control of pH	No No Yes	Yes Yes	Yes Yes	**SSM2** **SSM3** **CCP4**
19	Mould removal/ placement in brine	Biological/ physical	Contamination from equipment and personnel Growth of undesirable micro-organisms	Yes Yes	Regular cleaning and disinfection, GMPs Adjustment of room temperature	No No	Yes No	Yes	**SSM2** **SSM3**
	Dry-salting/ surface abrasion	Biological/ physical	Contamination from equipment and personnel Growth of undesirable micro-organisms, insufficient quantity of salt	Yes Yes	Regular cleaning and disinfection, GMPs Adjustment of room temperature	No No	Yes No	Yes	**SSM3**
18	Ripening	Biological	Failure to remove moisture Growth of undesirable micro-organisms	Yes	Regular salting Temperature control and adjustment of moisture in the chamber of ripening	Yes			**CCP5**
22	Washing/ drying	Biological	Presence of pollutants and points of contamination on the surface Moisture points on the surface of kasseri, mould growth	Yes	GMPs Macroscopic control before packaging	No	No		
24	Paraffin formation/ packaging	None							
25	Cooling	Biological	Growth of micro-organisms Release before the end of ripening	Yes Yes	Temperature control of cooling chambers Control of pH, production dates	Yes			**CCP6**

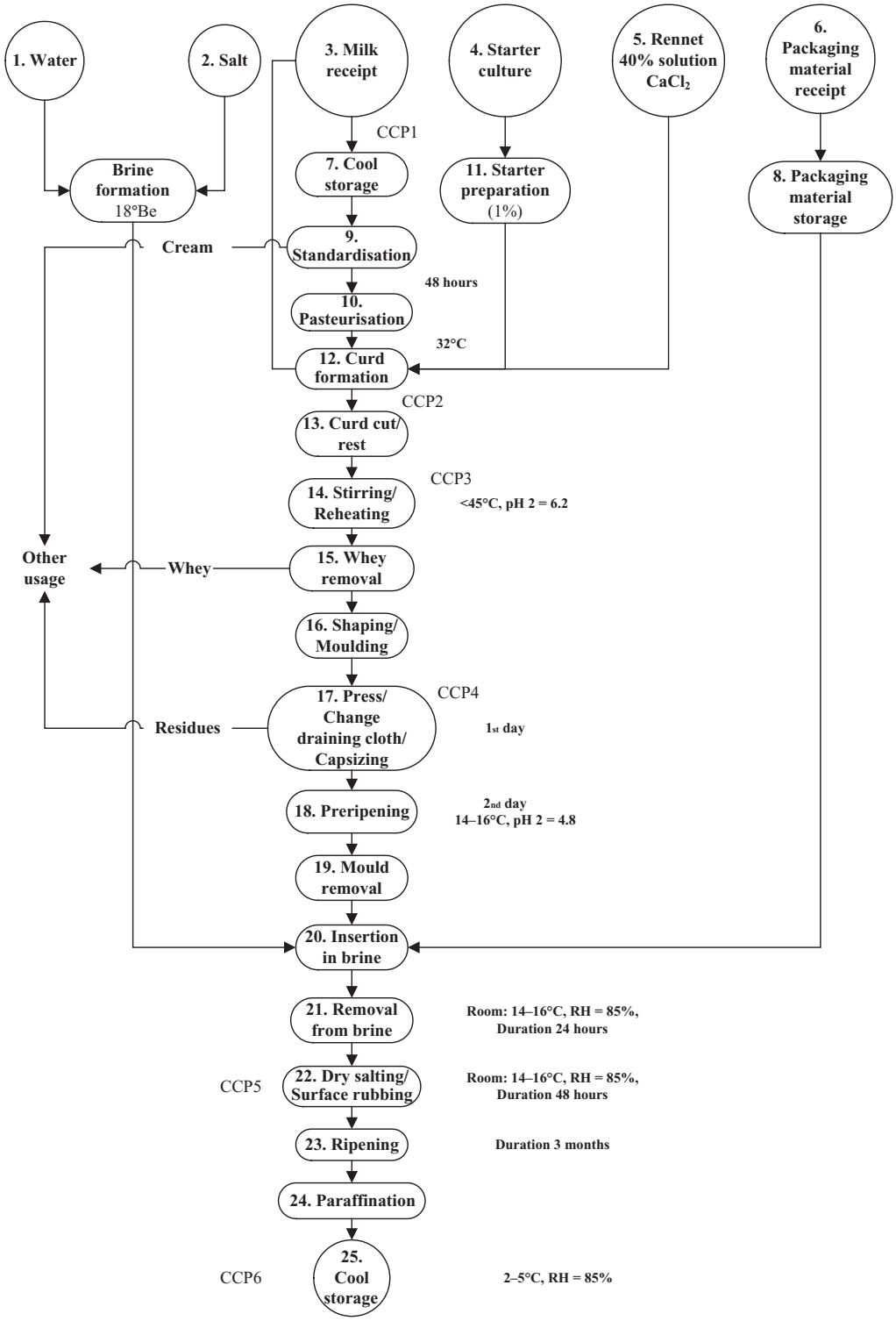

Fig. 3.4 Graviera/hard cheese/Kefalotyri flow diagram.

3.5.3 Starter culture

The product standardisation is assured with the addition of a thermophilic starter culture. The thermophilic cultures usually contain *Str. salivarius* subsp. *bulgaricus* and various strains of lactobacilli, such as *Lb. delbrueckii* subsp. *bulgaricus* and *Lb. delbrueckii* subsp. *lactis* (Caric, 1993). Formation of lactic acid by the starter bacteria is very important for the appropriate ripening and preservation of the cheese. The percentage of added culture is approximately 1.5% (Zerfiridis, 1997).

3.5.4 Rennet addition

Rennet is added to milk at 32°C after 30 minutes have elapsed from the starter culture addition. The rennet must be obtained from a certified supplier. The liquid rennet 1:10,000 gives the best quality of cheese. Incubation at 32°C continues until the formation of curd (35–40 minutes). The curd formation must follow a correct pattern. Curd formation time, temperature and acidity of milk are regarded as the monitoring parameters at this stage. Verification includes the inspection of plant records and the control of coagulum properties.

3.5.5 Ripening

The curd remains in the vat, dipped in the whey, at 38–42°C. The starter culture continues to reduce the pH of coagulum. Ripening is completed within 3–6 hours, when the pH reaches 5.1–5.2 or the acidity of whey attains 60–70°D. The end of curd ripening should be checked by experienced personnel. Potential cross-contamination of the curd from personnel and environment may favour the growth of pathogens in the final product.

3.5.6 Kneading

The curd is cut into slices which are transferred to a machine for mechanical kneading thus avoiding any microbial contamination. Kneading is carried out in hot water (80°C) for 15 minutes. The kneaded cheese at 57°C is filled in the moulds in a room without draught. The microbial and the chemical quality of water should be checked.

3.5.7 Pressing/salting (Kefalotyri cheese)

At Kefalotyri cheese production the cheese is transferred in plastic moulds, wrapped in clean cloths, pressed and salted in brine in contrast to Kasseri cheese. With pressing the cheese develops a very distinct and firm rind, free of visible openings, which can constitute pollution sites for mould strains. The main hazards consist of contamination from pressing and the salting environment, the quality of salt and water and the growth of moulds during salting. The environment is monitored for the absence of mould spores and records are kept. Air quality should be controlled by means of air filters and the critical limit is <100 moulds and yeasts per cubic metre (Hocking, 1997).

Kefalotyri cheese is pressed for 3–4 hours at 15°C and after pressing is placed immediately in brine (18°Bé) at 15°C. The pressure increases progressively until the pressure value reaches 12 times of cheese weight. During cheese salting, pH and salt content should be inspected and records should be kept. The presence of salt in moisture helps to control the growth of micro-organisms especially coliforms, staphylococci and clostridia. If weaker brines are used, growth of salt tolerant lactobacilli in the brine may be observed and flavour defects in cheese quality may occur. Placement of brined cheese under UV irradiation bulbs aims at inactivating the spores of moulds thus resulting in superficial disinfection.

Brine temperature and pH should be regularly checked and recorded. These parameters can be used as indicators for ensuring the desirable ripening process. Every six ± eight months, the brine should be changed and regular cleaning of the equipment is conducted.

Before the beginning of dry-salting, pH value is checked (4.8). Dry-salting is completed within 20–25 days. Control measures include the degree and distribution of salt, time and number of dry-salting, pH values and humidity. The temperature and RH (%) are held at 15°C and 80%, respectively. At higher RH (%) moulds may grow.

3.5.8 Dry-salting

The hazards include potential growth of undesirable micro-organisms, the quality of salt which may contain metals (physical hazard) or chemical substances at high concentrations and microbial contamination from the environment, water and personnel.

The salt concentration and its uniform distribution throughout the curd are important for ensuring a standard cheese quality. The control measures include degree and distribution of salt, duration and number of dry-salting for every cheese surface and titratable acidity. Dry-salting is completed within 15–30 days.

Verification includes monitoring of the quality of the end product and the inspection of plant records. During ripening the surface of the cheese is washed 1–2 times with lukewarm water, brushed and applied with brine. Ripening storage premises must be

free from draughts and insects. The temperature and the RH (%) are held at 15°C and 80%, respectively. At higher temperatures the fat may come out of the cheese.

3.5.9 Packaging

After ripening the cheeses are removed by the first in first out (FIFO) method and are prepared for packaging. The hazards are that the cheeses can be cross-contaminated by the packaging material (Cryovac) and the environment. If the packages happen to be sealed non-hermetically, moulds can grow at the surface of the cheese. The preventative measures consist of measuring the vacuum in packaged cheese and controlling the prescriptions for packaging material. The latter must be kept under strict hygienic conditions and the temperature should be held at 12°C.

3.5.10 Storage

When the cheeses are transferred to the storage room their uniform cooling should be checked. During storage the product temperature must be maintained at 5°C or less in order to ensure the microbiological safety of this product. The product must be kept at least for three months before consumption. The shelf life of this product is approximately one year. The control measures include pH of cheeses, duration of ripening (3 months), temperature and RH (%) of the storage room (Arvanitoyannis and Mavropoulos, 2000).

3.6 MANOURI CHEESE

Manouri cheese is one of the most popular white soft whey cheeses produced in Macedonia (northern Greece). It is produced from the whey derived from full-cream goat's milk or from mixtures of sheep's and goat's milk during the production of hard cheeses (Anifantakis, 1991b). Cream and/or milk may also be added. It is in the shape of a cylinder and does not have any holes. It is considered the highest quality whey cheese. The moisture, the fat and the salt content are 48, 37 and 0.8%, respectively. Furthermore, it has a high nutritional value due to its high biological value proteins content, higher than the biological value of caseins of which most cheeses consist. Since the whey cheeses are characterised by a great variety in their composition, special concern is required for maintaining the appropriate hygienic conditions in the production line in order to avoid the uncontrolled growth of microflora.

All the ingredients used, such as whey, milk, cream and salt constitute potential hazards. Therefore, they should be of controlled quality and purchased only from reputable suppliers. Acidification of whey is required to pH 5.8, before or during heating, when the pH value is high (pH > 6.0) in order to avoid the growth of *C. botulinum*. The added acids are citric, lactic and acetic acid. The heating rate must be controlled in order to reach the final temperature of 88–90°C within 40–45 minutes (Kalantzopoulos, 1993; Veinoglou *et al*., 1984). The heat treatment aims at the separation of proteins and fat as curd and at the destruction of the vegetative forms of bacteria. Cross-contamination of product after production leads to the growth of a high number of micro-organisms (coliforms, yeasts and moulds), due to the high moisture content.

If the hygienic conditions are not strictly adhered to after heat treatment, the addition of a starter culture (1%) is recommended, when the curd temperature is below 50°C. Recording of temperature during heat treatment should be carried out by experienced personnel using temperature recording charts. When the temperature increases, the ingredients must be added at 70–75°C (Greek Codex of Foods and Drinks, 1998). For the purpose of drainage, moulds and/or cloth bags are used. Potassium sorbate solution (15%) is added to the cheeses for a few seconds to avoid the growth of moulds later during storage. The cheese, in its final form, has the shape of a cylinder (diameter, 10–12 cm; length, 20–30 cm). Manouri cheeses are vacuum packed in plastic bags and can be consumed right after production, without ripening. The high moisture and lactose content make the product very vulnerable to micro-organisms. Therefore, it should be stored at cooling temperatures (<4°C) and consumed within 10–15 days. The shelf life of the product made from ultra-filtrated whey can be extended even for up to six months, without any alteration of the desirable organoleptic characteristics (Veinoglou and Kandarakis, 1984). If the temperature exceeds 4°C, there is a great risk of toxin growth producing moulds (Mauropoulos and Arvanitoyannis, 1999). The determination of CCPs and the flow diagram for Mizithra, Anthotyros and Manouri are given in Table 3.24 and Fig. 3.5, respectively.

3.7 ICE CREAM

Ice cream still retains a reputation as a high-risk food, although its safety record in developed countries has been very good over many years. This record can be attributed to the use of high-quality ingredients, the strict control of pasteurisation of the mix and the high level of hygiene during subsequent operations up to the point of sale.

Table 3.24 Determination of critical control points (CCPs) for Mizithra/Anthotyros/Manouri.

S/n	Processing step	Hazard	Description of hazards	Q1	Preventive action	Q2	Q3	Q4	α/α CCP
2	Milk receipt	Biological	Milk with high microbial load	Yes	Periodical control of milk sample	No	Yes	Yes	CCP 1a
			Distribution under non-hygienic conditions	Yes	Determination of pH	Yes	Yes	Yes	1b 1c
		Physical	Foreign matter, hair and other material	Yes	Control of temperature of receipt and cleaning of the vehicle	Yes No	Yes	No	1d
		Chemical	Antibiotics, pesticide residues	Yes	Filtration, macroscopic control	No			
			Adulterated milk (with water or cheaper milk)	Yes	Periodical control of milk for antibiotic residues Determination of specific gravity Instructions to producers and sign of agreements for standard specifications (TPC, somatic cells, antibiotics, fat concentration)	Yes			
4, 10	Receipt of whey/ filtration	Biological	Whey loaded with micro-organisms, low yield	Yes	Control of acidity, use of fresh whey Filtration	No	Yes	Yes	CCP2
		Physical	Residence of cheese crumbs, burning during pasteurisation	Yes		Yes			
1	Salt	Biological	Contaminated raw materials Use after expiry date	Yes	Reliable suppliers, raw materials conforming to the legislation Implementation of FIFO	No	No	Yes	
		Physical	Presence of foreign matter	Yes	Macroscopic control before use	No	No		
		Chemical	Presence of heavy metals	Yes	Reliable suppliers, raw materials conforming to the legislation	No	Yes		
12, 13	Receipt–storage of packaging materials	Biological	Presence of contaminants and foreign matter	Yes	Macroscopic control. Ideal storage conditions/cleaning	No No	Yes Yes	Yes Yes	
		Physical	Moisture uptake	Yes	Conformity certificates for the use of packaging materials in the food industry	No	No		
		Chemical	Packaging materials non-conforming to come into contact with food	Yes					
15	Pasteurisation/ baking of cheese curd	Biological	Survival of pathogenic micro-organisms, weakness of satisfactory reduction of the initial microbial load	Yes	Control of time and temperature of pasteurisation	Yes			CCP3
18	Collection/ moulding	Biological/ physical	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No	Yes	No	
19	Draining	Biological/ physical	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No	Yes	No	
		Biological	Inability to remove moisture, prevailing of good micro-organisms	Yes	Control of room's conditions	Yes			

(*Continues*)

Table 3.24 (Continued)

S/n	Processing step	Hazard	Description of hazards	Q1	Preventive action	Q2	Q3	Q4	α/α CCP
20	Mould removal	Biological/ physical	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No	Yes	No	
21	Stay on the cheese table	Biological/ physical	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No	Yes	No	
			Growth of undesirable micro-organisms	Yes	Adjustment of room temperature	No	Yes	No	
22	Packaging	Biological/ physical	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No Yes	Yes	No	
		Biological	Failure of vacuum operation		Operation control, control of closure				**CCP4**
23	Cooling	Biological	Growth of micro-organisms	Yes	Temperature control of cooling chambers	Yes			**CCP5**
			Release before the end of ripening	Yes	Control of pH, production dates				
	Distribution	Biological	Growth of undesirable micro-organisms	Yes	Control of temperature of vehicles	Yes			**CCP6**

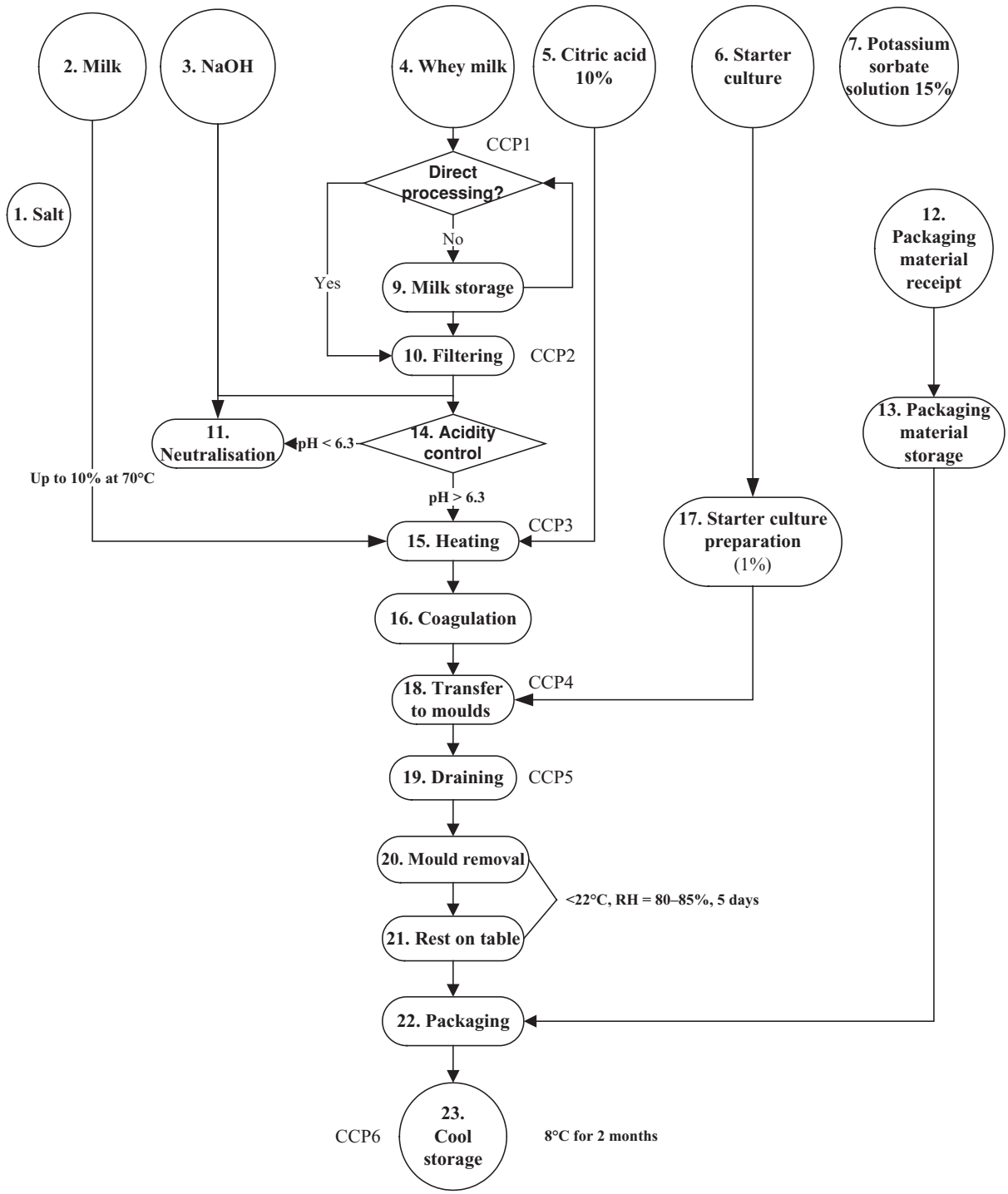

Fig. 3.5 Mizithra/Anthotyros/Manouri flow diagram.

Nevertheless, even if ice cream has not been the vehicle of major food poisoning outbreaks, complacency should be avoided. The isolation of *Listeria monocytogenes* from ice cream in the USA (Varnam and Sutherland) underlines the necessity of re-evaluating the process with respect to this micro-organism. *Salmonella* and *Listeria* are in practice of the greatest concern and should be tested for by standard cultural techniques or rapid tests. Moreover, additions made to ice cream after pasteurisation are potential sources of hazard and under some circumstances microbiological examination should be considered.

To conclude, micro-organisms are unable to grow in ice cream if stored at adequate temperatures. Pasteurisation of the mix involves elimination just of the vegetative pathogens; therefore, it is of paramount importance to: prevent recontamination after pasteurisation, assure the microbiological status of ingredients with particular reference to thermoduric micro-organisms and the preformed toxins, prevent microbial growth before freezing and ensure the continuity of the freezing chain up to consumption. The ice cream description, determination of CCPs, the HACCP plan, hazards identification and the flow diagram for ice cream are given in Tables 3.25–3.28 and Fig. 3.6, respectively.

Roughly speaking, ice cream manufacture involves the following steps: blending, pasteurisation, homogenisation, ageing of the mix, freezing, packaging and hardening.

3.7.1 Blending

The liquid and dry ingredients are weighed and blended together by means of rapid agitation in high-speed blenders. It is of key importance that the dry ingredients disperse fully in the mix; therefore, blending tanks should be fitted with highly efficient turbine agitators. Dispersion can also be aided by introducing solid ingredients into the liquid in the pipe feeding the blending tank.

3.7.2 Pasteurisation

The mix should be heated to a level sufficient to destroy vegetative pathogens and especially *Listeria monocytogenes*. Moreover, pasteurisation also reduces the number of spoilage organisms such as psychrotrophs and helps to hydrate some of the components (proteins and stabilisers). Both batch pasteurisers and continuous (HTST) methods are used.

Table 3.25 Ice cream product description.

Product	Ice cream	
General characteristics	Pasteurised Deep frozen $a_w > 0.95$ No preservatives Contains nuts or may contain traces of nuts Sizes: stick 80 g, cone 78 g, cup 150 g, family size 500 and 1000 g	
Packaging/size	Wooden stick, laminated foil/pp film Cone sleeves Plasticised paper cups, paper lids PE containers, PE lids	Cardboard
Usage	Ready to eat	
Shelf life	18 months	
Storage and transport requirements	−20 to −26°C	
Foreign materials	Ferrous 1.5–2.0 mm Non-ferrous 2.5 mm Stainless steel 316 (2.5–3.0 mm)	
Microbiological standards	APC Coliform or Enterobacteria *Salmonella* spp. *Staphylococcus aureus* Yeasts Moulds Yeasts and Moulds	1×10^5 0/0.1 mL 0/25 mL As coagulase positive, 0/0.1 mL 1×10^2 1×10^2 1×10^2

Table 3.26 Determination of critical control points (CCPs) for ice cream.

S/n	Process	Hazard	Hazard description	PP	Q1	Q2	Q3	Q4	CCP
1	Water supply	Biological	Water not meeting potable water criteria	1					
		Chemical	Heavy metals, pesticides						
		Physical	Extraneous matter						
2	Raw material receipt	Biological	Pathogen growth/toxin production due to accepting temperature/time abused product	7	Yes	No	Yes	Yes	
		Chemical	Pathogen contamination from receiving equipment	4					
			Veterinary drug residues, heavy metals, pesticides	7					
			Cross-contamination from non-food chemicals (cleaners, sanitisers, lubricants)						
			Not food grade						
		Physical	Extraneous matter	7					
3	Packaging material receipt	Biological	Soiled packaging	7					
		Chemical	Not food grade						
		Physical	Extraneous matter						
4, 5	Raw and packaging material storage	Biological	Pathogen growth due to temperature and/or humidity abuse	3	Yes	Yes			1
			Contamination from unclean storage rooms	4					
		Chemical	Contamination from chemicals present in food storage rooms	4					
		Physical	Contamination from extraneous matter	4					
6	Recipe calculation/ weighing	Biological	Contamination from personnel and equipment	4, 5					
		Chemical	Exceed acceptable quantity of additive (i.e. of stabilisers)	4, 5					
		Physical	Contamination from extraneous matter	5					
7	Blending	Biological/ chemical	Contamination from personnel and equipment	4, 5					
		Physical	Contamination from extraneous matter	5					
8–10	Pasteurisation/ homogenisation/ cooling	Biological	Pathogen survival due to improper time/ temperature		Yes	Yes			2–3
			Pathogen recontamination due to improper pressure differential	2					
			Pathogen recontamination from raw product (product accumulation)	4, 5					
		Chemical	Cross-contamination from non-food chemicals (cleaners, sanitisers)	4, 5					
			Cross-contamination from heating and/or cooling media (pinholes)	2					
		Physical	Contamination from hazardous extraneous material (metal, gaskets)	2					
11	Flavour and colourant addition	Biological	Contamination from personnel and equipment	4, 5					
		Chemical	Cross-contamination from non-food chemicals (cleaners, sanitisers)	4, 5					
		Physical	Contamination from extraneous matter	5					

(*Continues*)

Table 3.26 (Continued)

S/n	Process	Hazard	Hazard description	PP	Q1	Q2	Q3	Q4	CCP
12	Ageing	Biological	Pathogen growth if temperature rises above 5°C.		Yes	No	Yes	No	4
			Contamination from unclean tanks	4, 5					
		Chemical	Cross-contamination from non-food chemicals (cleaners, sanitisers)	4, 5					
		Physical	Contamination from extraneous matter	2, 5					
13	Freezing with air incorporation	Biological	Contamination from air	2					
			Contamination from unclean equipment	2, 4					
		Chemical	Cross-contamination from non-food chemicals (cleaners, sanitisers)	4, 5					
		Physical	Contamination from extraneous matter	2, 5					
14	Chocolate melting	Biological	Contamination from unclean equipment	2, 4					
		Chemical	Cross-contamination from non-food chemicals (cleaners, sanitisers)	4, 5					
		Physical	Contamination from extraneous matter	2, 5					
15, 20	Metal detection	Physical	Risk of releasing contaminated end product from hazardous metal material due to improper functioning/calibration of metal detector	2	Yes	Yes			5
16–22	Mould filling-coating/ decoration	Biological	Contamination from unclean equipment	2, 4					
		Chemical	Cross-contamination from non-food chemicals (cleaners, sanitisers)	4, 5					
		Physical	Contamination from extraneous matter	2, 5					
23	Packaging/labelling	Biological	Pathogen contamination from physical damage to the container	2, 5					
24	Hardening	Biological	Inability to prevent microbial growth and achieve desirable shelf life		Yes	No	No		
			Contamination from unclean equipment	2, 4					
25	Storage/distribution	Biological	Pathogen growth due to abuse	3					

Table 3.27 HACCP plan for ice cream.

CCP	Process	Hazard description	Preventive actions	Monitoring procedures	Responsible	Critical control limits	Verification procedures	Corrective actions	HACCP records
1	4. Milk storage	Pathogen growth/toxin production from time and temperature abuse	Equipment maintenance/ calibration Training–critical control limits observance	Trained personnel to monitor the storage temperature and time of every raw milk storage tank and record on daily log	Storage personnel	Storage temperature <5°C Maximum storage period see expiry date	Maintenance supervisor will verify accuracy of the room temperature log once per shift and observe plant employee performing monitoring QA will check all thermometers used for monitoring devices for their accuracy on a daily basis	Hold affected storage tanks (not to be directed in production) Inform quality control supervisor and he/she to decide on disposition Quality control to investigate, identify and correct cause of problem	Raw milk storage temperature and time monitoring records and action taken records Thermometer calibration records Quality control audit records Affected load history
2	8. Milk pasteurisation	Pathogen survival due to improper time and/or temperature of pasteurisation	Equipment maintenance/ calibration Training–critical control limits observance	Operator monitors cut-in/cut-out temperature at start up for each batch Operator checks the indicating thermometer reading is equal to critical limits and is recorded on the pasteuriser chart Operator checks everyday that the seal is intact on flow control device	Pasteuriser operator	Pasteurisation temperature not less than 80°C for a holding time of not less than 25 seconds or 69°C/30 minutes	Specialist auditing and plate maintenance should be carried out twice a month Ensure correct operations at start of each run Twice a week examination of thermograph records Monthly microbiological tests meeting standards	Activate manual divert and hold all product processed since last satisfactory check Inform quality control supervisor and he/she to decide on disposition Quality control to investigate, identify and correct cause of problem	Calibration record Corrective action records Recording charts Quality control pasteurisation verification records Quality control audit records Product deviation records Records of discussions Equipment and control test records

(*Continues*)

Table 3.27 (Continued)

CCP	Process	Hazard description	Preventive actions	Monitoring procedures	Responsible	Critical control limits	Verification procedures	Corrective actions	HACCP records
3	10. Cooling	Inability to inactivate pathogen spores	Equipment maintenance/ calibration Training– critical control limits observance	Operator monitors cut-in/cut-out temperature at start up for each batch Operator checks the indicating thermometer reading is equal to critical limits and is recorded on the pasteuriser chart	Pasteuriser operator	Rapid cooling under 4°C within 1.5 hours Hold at this temperature not more than 24 hours	If a deviation is found on verification the HACCP coordinator assesses whether food safety has been affected and if it has will treat it as in the deviation procedure and retrain the employee responsible for the deviation.	A recall may be initiated if the product has left the facility	The deviation and corrective action will be recorded.
4	12. Ageing	Pathogen growth/toxin production from time and temperature abuse	Equipment maintenance/ calibration Training– critical control limits observance	Trained personnel to monitor the storage temperature and time of every raw milk storage tank and record on daily log	Pasteuriser operator	Temperature <5°C Time <24 hours	Quality of end product Number of psychotropic micro-organisms (twice a month) Twice a week inspection of records		

5	15/20. Metal detection	Release product containing ferrous fragments	Routine equipment check/ calibration	Function and sensitivity confirmation Packaging line supervisor will check the metal detector using a seeded sample every 2 hours to determine limits are not exceeded	Shift supervisor	Ferrous 1.5–2.0 mm Non-ferrous 2.5 mm Stainless steel 316 (2.5–3.0 mm) All contaminated product is removed from system by triggering kick out mechanism	QA, outside the packaging unit, will verify that the metal detector is functioning as intended by running the seeded sample through the metal detector twice per shift (once AM, once PM). QA will observe monitoring to assure that product from kick out is placed on hold	Reject Activate manual divert and hold all product processed since last satisfactory check Quality control to investigate, identify and correct cause of problem	Calibration record Corrective action records Quality Control audit records Product deviation records Equipment and control test records

Table 3.28 Hazards identification in incoming materials.

Incoming materials	Biological	Chemical	Physical
Packaging material	Pathogen contamination from soiled/damaged packaging materials	Not food grade	Hazardous extraneous material (glass, metal, wood)
Water	Water not meeting the drinking water criteria	Heavy metals, pesticides	Hazardous extraneous material (metal)
Dairy	Pathogens: *Listeria monocytogenes*, *Yersinia enterocolitica*, *Campylobacter jejuni*, *Bacillus cereus*, *Salmonella* spp., *Staphylococcus aureus*, *E. coli* (O157:H7), *Shigella* spp.	Veterinary drug residues, mycotoxins, pesticide residues, dioxins, PCBs	Hazardous extraneous material (glass, metal, wood)
Eggs	Pathogens: *Salmonella typhimurium*, *Salmonella enteritidis*, *Campylobacter jejuni*, *Yersinia enterocolitica*, *S. aureus*, *E. coli*	Veterinary drug residues, furans, dioxins, PCBs	Hazardous extraneous material (glass, metal, wood), egg shells
Chocolate	Pathogens: Enterobacteriaceae, *Salmonella* Spoilage from: *Bacillus coagulans* and *Bacillus stearothermophilus*	Pesticide residues, ochratoxin A	Hazardous extraneous material (glass, metal, wood)
Isoglucose/glucose/ sugar	Spoilage from: *Bacillus coagulans*, *Bacillus stearothermophilus*, *Clostridium thermosaccharolyticum*, *Desulfotomaculum nigrificans*	Pesticide residues, heavy metals	Hazardous extraneous material (glass)
Additives		Not food grade	Hazardous extraneous material (glass, metal, wood)
Fruit pieces	Pathogens: *Salmonella* spp., *Listeria monocytogenes*, *Shigella* spp., *B. cereus*, *S. aureus* Spoilage from: Yeasts, fungi, *Erwinia*	Pesticide residues	Hazardous extraneous material (glass, metal, wood)
Dry nuts	*Aspergillus flavus*, *Aspergillus parasiticus*	Pesticide residues, aflatoxins	Hazardous extraneous material (glass)
Cones/waffles			Hazardous extraneous material (glass, metal, wood)

Low temperature–long time pasteurisation, which takes place in a steam or water jacketed vat, results in more whey protein denaturation, giving a better body to the ice cream. The product is heated in the vat to at least 69°C and held for 30 minutes to satisfy legal requirements for pasteurisation, necessary for the destruction of pathogenic bacteria. Various time and temperature combinations can be used. The heat treatment must be severe enough to ensure destruction of pathogens and to reduce the bacterial count to a maximum of 100,000 per gram. Following pasteurisation, the mix is homogenised by means of HPs and then is passed across some type of heat exchanger (plate or double or triple tube) for the purpose of cooling the mix to refrigerated temperatures (4°C). Batch tanks are usually operated in tandem so that one is holding while the other is being prepared. Automatic timers and valves ensure the proper holding time has been met.

Plate heat exchangers are commonly used for HTST processing, although tubular heaters may be preferred where space is limited. Some preheating, 30–40°C, is necessary for the components to dissolve easily. The HTST system is equipped with a heating section, a cooling section and a regeneration section. Cooling sections of ice cream mix HTST presses are usually larger than milk HTST presses. Because of the preheating of the mix, regeneration is lost and mix entering the

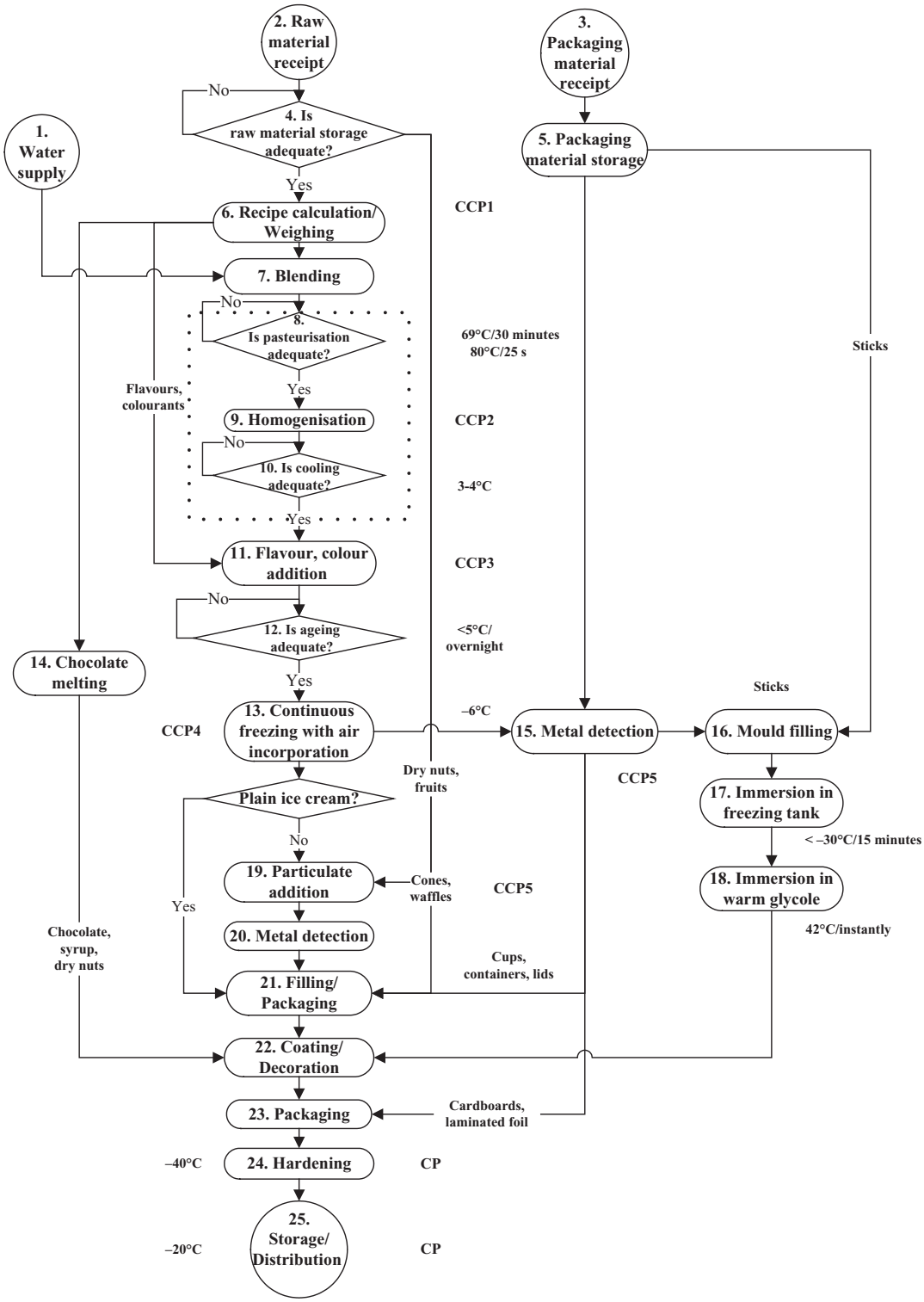

Fig. 3.6 Ice cream manufacturing flow diagram.

cooling section is still quite warm. Fouling is a serious potential problem during HTST pasteurisation but can be minimised by taking rigorous precautions against the incorporation of excess air into the mix.

3.7.3 Homogenisation

The reduction of the size of fat globules is required during ice cream manufacture to prevent churning and to improve whipping properties and air incorporation by allowing proteins to absorb onto the surface of fat globules. This is accomplished by means of homogenisation, a process that reduces the size of the fat globules found in milk or cream to less than 1 μm. Two-stage homogenisation (15 MPa in the first and 4 MPa in the second stage) is usually preferred for ice cream mix. Clumping or clustering of the fat is reduced thereby producing a thinner, more rapidly whipped mix. Meltdown is also improved. Homogenisation of the mix should take place at the pasteurising temperature. The high temperature produces more efficient breaking up of the fat globules at any given pressure and also reduces fat clumping and the tendency to thick, heavy-bodied mixes. The higher the fat and total solids in the mix, the lower the pressure should be.

3.7.4 Ageing

The mix is then aged for at least four hours and usually overnight. This allows time for the fat to cool down and crystallise and for the proteins and polysaccharides to fully hydrate. Ageing improves whipping qualities of mix and body and texture of ice cream. Ageing is performed in insulated or refrigerated storage tanks, silos etc. Mix temperature should be maintained as low as possible without freezing, at or below 5°C. The longer the ageing time, the better the results under average plant conditions. A 'green' or unaged mix is usually quickly detected at the freezer.

3.7.5 Freezing and hardening

Traditionally, ice cream freezing is a two-stage process. In the first stage, the temperature is reduced under stirring, air being incorporated to give an aerated product. The second stage, which is much slower, involves no air incorporation and takes place under quiescent conditions in a hardening room or tunnel. The process is not complete and even at very low temperatures some water remains unfrozen.

Freezing takes place in a 'barrel' freezer; a scraped-surface, tubular heat exchanger, which is jacketed with a boiling refrigerant such as ammonia or Freon. Mix is pumped through this freezer and is drawn off the other end in a matter of 30 seconds (or 10–15 minutes in the case of batch freezers) with about 50% of its water frozen. Inside the barrel, there are rotating blades that keep the ice scraped off the surface of the freezer and also dashers inside the machine which help to whip the mix and incorporate air.

The crystallisation stage is of major importance as the texture of ice cream is largely determined by the size of the ice crystals. Fast freezing rates decrease the size of crystals rendering the mundetectable in the mouth.

Flavouring, colouring and finely chopped fruit and nuts may be added to the mix directly before freezing, whereas larger pieces must be added as the ice cream leaves the freezer.

After the particulates have been added, ice cream is packaged and placed into a blast freezer at −30 to −40°C where most of the remainder of the water is frozen. Below −25°C, ice cream is stable for indefinite periods without danger of ice crystal growth; however, above this temperature, ice crystal growth is possible and the rate of crystal growth is dependent upon the temperature of storage, limiting the shelf life. Hardening is the static (still, quiescent) freezing of the packaged products in blast freezers. Freezing rate must still be rapid, so freezing techniques involve low temperature (−40°C) with either enhanced convection (freezing tunnels with forced air fans) or enhanced conduction (plate freezers).

3.8 HARD ITALIAN CHEESES (PROVOLONE, ROMANO AND PARMESAN)

Provolone cheese belongs to the pasta filata class of Italian cheeses, characterised by the working of curd in hot water until it becomes a close-knit, elastic mass followed by moulding of curb into the desired shape (Wilster, 1997). Provolone cheese is used as a table cheese and is preferred for its piquant flavour, due to the action of several bacteria and a lipase and is enhanced by a light smoking. Romano cheese is a very hard cheese, has a sharp, piquant taste, granular texture and a few holes, and is usually consumed as grating cheese. Parmesan cheese is also a very hard grating cheese and has sensory properties similar to Romano cheese. The typical compositions of these cheeses are (i) Provolone: moisture <45% and fat in dry matter 46–47%, (ii) Romano: <34% and fat in dry matter >38% and (iii) Parmesan: moisture <32% and fat in dry matter >32% (Sandrou and Arvanitoyannis, 2000b).

The flow diagram for the production of these hard cheeses is outlined in Fig. 3.7. Although there is not just one manufacturing process applied in this industry, Provolone and Romano cheeses are manufactured from either raw or HTST pasteurised standardised

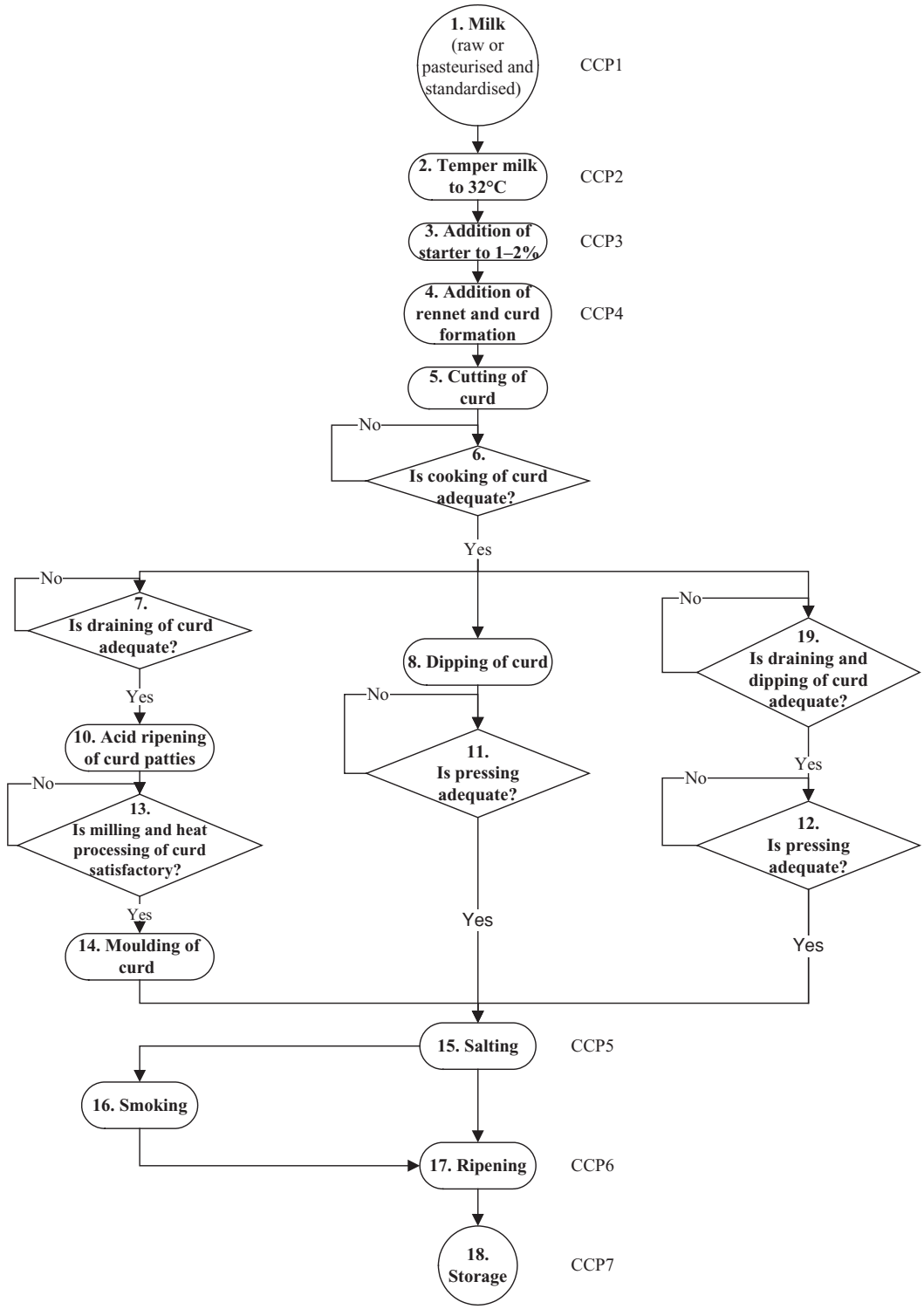

Fig. 3.7 Hard Italian cheeses manufacturing flow diagram.

Table 3.29 Strains, cooking conditions, acidity, salting and ripening conditions of hard Italian cheeses.

Hard Italian cheese	% Strain	Cooking conditions (°C, time)	% Acidity	Salting (% brine salt, °C, time)	Ripening (°C, time)
Provolone	1–1.5 *Lb. delbrueckii bulgaricus*	48°C × 45 minutes	0.14–0.16	23% 7°C × 1–3 days	13°C × 4 weeks
Romano	1–1.5 *Str. thermophilus* and *Lb. delbrueckii bulgaricus* (1:1)	47°C × 45 minutes	0.2	23% 2–5 days	10–13°C × 5–12 months
Parmesan	0.7 *Lb. delbrueckii bulgaricus*, 0.75 *Str. thermophilus* and 0.5 LAB	50°C × 60 minutes	0.14–0.16	24% 14–15 days	16°C until 15% weight reduction

milk, while Parmesan cheese is produced only from HTST pasteurised standardised milk. Cheese milk should be a premium quality and should comply with the prescribed requirements for the milk used in Feta cheese. Starters for each cheese consist of different strains and are used at different proportions (Table 3.29). Starters are usually incubated in whey until 0.8% acidity is reached at 43–46°C. Whey used for culture incubation should be first heated at least at 82°C for 30 minutes, in order to minimise the potential problems caused by bacteriophages present in the whey obtained from cheese vats (Wilster, 1997). Two or three strain cultures should be used with or without rotation and phage-sensitivity should be monitored on a daily basis. Phage-sensitive strains should be removed from use and should be replaced with resistant strains (Varnam and Sutherland, 1996). Rennet addition and curd formation should be carried out at 32°C and should be supervised by experienced personnel.

When the acidity of Provolone curd reaches 0.14–0.16%, the curd should be drained, cut into patties and left on the vat floor for 2 hours to obtain the optimum acidity of 0.6–0.8% (pH of 5.1–5.2). After acid ripening of curd, Provolone should be milled to the correct size and curd strips should be left for 15 minutes in the vat containing 77–82°C hot water. During kneading, potential cross-contamination of curd should be avoided and water of potable quality should be used. Romano curd is drained, partly salted and placed in cloth-lined hoops. The initial whey draining from the hoops should have a titratable acidity of 0.25–0.3%. The curd is pressed at 69 kPa for 20 minutes, removed from the moulds, reversed, replaced into moulds, and re-pressed for 60 minutes or even longer. Parmesan curd, on the other hand, is partially drained, stirred gently for 15–20 minutes and dipped into cloth-lined metal hoops. Afterwards, the curd is pressed at 69 kPa for 30 minutes at room temperature and re-pressed at 138 kPa overnight. After salting, smoking of Provolone cheese follows. Smoking temperature and duration should be monitored to avoid excessive smoking, which degrades the flavour of the end product (Sandrou and Arvanitoyannis, 2000b).

During ripening, it is important to monitor temperature, RH and hygienic condition of the ripening room. After ripening, Provolone should be stored at 4°C for 2–12 months, Romano should be vacuum packaged and stored at 4°C for 10 months and Parmesan should be stored at 2°C for 10 months. During storage, the temperature should be constantly monitored and adequacy of vacuum and seam integrity should be periodically checked (Sandrou and Arvanitoyannis, 2000a). A tentative determination of CCPs for hard Italian cheeses is given in Table 3.30.

3.9 CHEDDAR CHEESE

Cheddar cheese is one of the most important varieties of hard cheeses and is characterised by the salting of the cheese mass prior to moulding and pressing of the cheese, causing retardation of the rate of acid development. Acidity is produced in the cheese vat by the starter culture, which is characterised by the absence of lactobacilli. Cheddar cheese has a pleasant taste, compact texture and few mechanical holes (Zerfiridis, 1994). The typical composition of Cheddar cheese has moisture content lower than 39% and fat –in –dry matter higher than 50% (Sandrou and Arvanitoyannis, 2000b).

Preparation of equipment refers to cleaning and sanitisation of cheese-making equipment and accessories. Cheese milk should be received and processed only in thoroughly cleaned and properly sanitised equipment. Non-hygienic conditions during manufacture will cause contamination, thereby impairing the quality of the finished cheese. All cheese-making equipment and accessories should be sterilised just before use by contact with hot water (at 82°C/180°F) or chlorine solution (having 100 ppm available chlorine) for at least 2 minutes (De, 2000).

Table 3.30 Determination of critical control points (CCPs) for hard Italian cheeses (Provolone, Romano and Parmesan).

S/N	Processing step	Hazard	Description of hazards	Q1	Preventive action	Q2	Q3	Q4	α/α CCP
1, 2	Milk receipt/ temper milk	Biological	Milk with high microbial load	Yes	Periodical control of milk sample	No	Yes	Yes	**CCP 1a**
				Yes	Determination of pH	Yes			**1b**
			Distribution under non-hygienic conditions	Yes	Control of temperature of receipt and cleaning of the vehicle	Yes			**1c** **1d**
		Physical	Foreign matter, hair and other material	Yes	Filtration, macroscopic control	No	Yes	Yes	
					Periodical control of milk for	No	Yes	No	
		Chemical	Antibiotics, pesticide residues	Yes	antibiotic residues	Yes			
			Adulterated milk (with water or cheaper milk)		Determination of specific gravity Instructions to producers and sign of agreements for standard specifications (TPC, somatic cells, antibiotics, fat concentration)				
3	Addition of starter	Biological	Whey loaded with micro-organisms, low yield	Yes	Acidity control, use of fresh whey	No	Yes	Yes	**CCP2**
		Physical	Stay of cheese crumbs, burning during pasteurisation	Yes	Filtration	No	Yes	Yes	
6	Rennet Curd formation	Physical	Presence of foreign matter	Yes	Macroscopic control before use	No	Yes	Yes	**CCP3**
		Chemical	Presence of heavy metals	Yes	Reliable suppliers, raw materials conforming to the legislation	No	No		
		Biological	Slow growth of "good" micro-organisms, prevailing of undesirable and harmful ones	Yes	Weigh rennet Monitoring of temperature of cheese boiler Monitoring of curdling time Control of milk temperature	Yes			
7, 8, 9	Draining/ dipping of curd	Biological/ physical	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No	Yes	No	
		Biological	Inability to remove moisture, prevailing of good micro-organisms	Yes	Control of room's conditions	Yes			
10	Ripening	Biological	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No	Yes	Yes	
11, 12	Pressing	Biological/ physical	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs. Use of appropriate weights,	No	Yes	Yes	
			Unable to remove the required quantity of whey	Yes	adjustment of room temperature	No	No		

(*Continues*)

Table 3.30 (Continued)

S/N	Processing step	Hazard	Description of hazards	Q1	Preventive action	Q2	Q3	Q4	α/α CCP
13	Milling	Biological/ physical	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No	Yes	Yes	
15	Salting	Biological/ physical	Contamination from equipment and personnel Growth of undesirable micro-organisms, insufficient quantity of salt	Yes Yes	Regular cleaning and disinfection, GMPs Adjustment of room temperature	No No	Yes No	Yes	
17	Ripening	Biological	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No	Yes	Yes	
18	Storage	Biological	Growth of micro-organisms Release before the end of ripening	Yes Yes	Temperature control of cooling chambers Control of pH, production dates	Yes			CCP4

The microbiological safety of Cheddar cheese mainly depends on the proportion, quantity and type of acid produced during the lactic fermentation. Pasteurisation of raw milk and prevention of recontamination of pasteurised milk should be ensured to avoid growth of *S. aureus* and *Salmonella* and production of enterotoxins by *S. aureus* (Hendricks *et al*., 1959; Zehren and Zehren, 1968). The conditions that flavour the growth of pathogens and enterotoxins production in Cheddar cheese have been extensively studied (Geopfert and Biggie, 1968; Hargrove *et al*., 1969a; Ibrahim *et al*., 1981; Park *et al*., 1970; Reiter *et al*., 1964; Tatini *et al*., 1971; Tuckey *et al*., 1964; Walker *et al*., 1961; White and Custer, 1976). The traditional process for making Cheddar cheese is outlined in Fig. 3.8. All stages prior to scalding of the curd should comply with the prescribed requirements for Feta cheese, apart from the differences that originate from the use of sheep's milk. Milk should be standardised to a casein/fat ratio of 0.69–0.71 before pasteurisation. After cooling of the pasteurised milk to 30°C, a lactic culture of *Lactococcus lactis* or *L. cremoris* is added. Starters should begin acid production within 30–45 minutes, should be free of bacteriophages (Canteri, 1997; Chopin, 1997) and should exhibit stability to ageing (Haque *et al*., 1997). The lactic culture plays a determining role for Cheddar manufacture because it produces sufficient acid, inhibits growth of pathogens, and improves the texture, consistency and flavour of the cheese (Litopoulou-Tzanetaki, 1993). The determination of CCPs for Cheddar cheese is given in Table 3.31.

The milk grader in a cheese factory has to perform his task conscientiously from day to day. He should intercept any can/tanker of inferior milk and not allow it to get mixed up with high-grade milk. Successful cheese factories follow a system of daily, efficient grading of all milk received. This consists of:

(i) Determining the odour of the milk in each can/tanker. No off-flavour should be accepted.
(ii) Inspecting the appearance of the milk, this should be free from all extraneous matter.
(iii) Determining sediment, either once a week or every 10 days, in each can of milk (a minimum amount of sediment is desirable).
(iv) Performing MBR, Resazurin and Rennet-curd tests on the milk once a fortnight or so for each producer/supplier and more frequently (weekly or even daily) on milk of doubtful quality.
(v) Determining the percentage of titratable acidity (there should be as little developed acidity as possible).
(vi) Examining milk for bacteriophages, antibiotics and inhibitory substances (De, 2000).

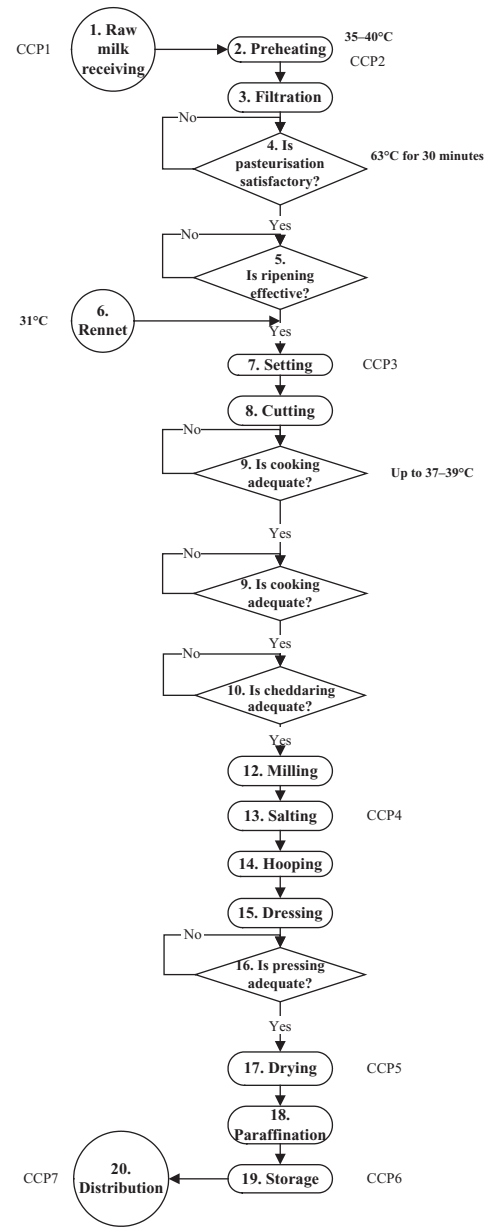

Fig. 3.8 Cheddar cheese manufacturing flow diagram.

Throughout Cheddar manufacture, pH, acidity, moisture content and consistency of the product should be constantly monitored to verify that all stages are performed correctly. The equipment used should be well maintained and disinfected to avoid both damage and contamination of curd (IDF, 1997; Parmentier, 1997). Heating at 38°C leads to curd shrinking and whey expulsion and it should be terminated when the titratable acidity of the whey reaches 0.14–0.16% and

Table 3.31 Determination of critical control points (CCPs) for Cheddar cheese production.

S/N	Processing step	Hazard	Description of hazards	Q1	Preventive action	Q2	Q3	Q4	α/α CCP
1	Milk receipt	Biological	Milk with high microbial load	Yes	Periodical control of milk sample	No	Yes	Yes	**CCP 1a**
				Yes	Determination of pH	Yes	Yes	Yes	**1b**
			Distribution under non-hygienic conditions	Yes	Control of temperature of receipt and cleaning of the vehicle	Yes	Yes	No	**1c** **1d**
		Physical	Foreign matter, hair and other material	Yes	Filtration, macroscopic control	No			
		Chemical	Antibiotics, pesticide residues	Yes	Periodical control of milk for antibiotic residues	No			
			Adulterated milk (with water or cheaper milk)		Determination of specific gravity	Yes			
					Instructions to producers and sign of agreements for standard specifications (TPC, somatic cells, antibiotics, fat concentration)				
4	Preheating	Biological	Survival of pathogenic micro-organisms, unsatisfactory reduction of the initial microbial load	Yes	Control of time and temperature of pasteurisation	Yes			**CCP2**
5	Ripening	Biological	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No	Yes	Yes	
6	Rennet	Physical	Presence of foreign matter	Yes	Macroscopic control before use	No	Yes	Yes	**CCP3**
9	Cooking	Biological	Growth of micro-organisms	Yes	Temperature control of cooking	Yes	Yes	Yes	
			Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No			
10	Draining	Biological/ physical	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No	Yes	No	
				Yes		Yes			
		Biological	Inability to remove moisture, prevailing of good micro-organisms		Control of room's conditions				
12	Milling	Biological/ physical	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No	Yes	Yes	
13	Salting	Biological/ physical	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No	Yes	Yes	**CCP4**
				Yes		No	No		
			Growth of undesirable micro-organisms, insufficient quantity of salt		Adjustment of room temperature				
16	Drying	Biological/ physical	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs Use of appropriate weights, adjustment of room temperature	No	Yes	Yes	**CCP5**
				Yes		No	No		
			Unable to remove the required quantity of whey						
19	Storage	Biological	Growth of micro-organisms	Yes	Temperature control of cooling chambers Control of pH, production dates	Yes			**CCP6**
			Release before the end of ripening	Yes					
20	Distribution	Biological	Growth of undesirable micro-organisms	Yes	Control of temperature of vehicles	Yes			**CCP7**

the pH value reaches 6.0–6.1 (ICMSF, 1988). Draining and texturisation of the curd should be performed at the correct time, to the proper extent, and at the appropriate temperature by experienced personnel (Varnam and Sutherland, 1996). The characteristic process of 'cheddaring' should start when the curd pieces are still hot and it should be completed when curd pieces become one mass. Salting of the curd affects ripening, flavour development, preservation and rind formation of Cheddar cheese and is considered as a CCP because it affects the growth of *S. aureus* and death rate of *Salmonella*. Salt concentration should be around 2%, unless there is a deviation from the normal rate of acidity development. Gradual pressing (maximum 1.7 atm) makes the curd more compact by completing whey removal. After pressing, vacuum packaging in plastic film or Cryovac and cooling of the Cheddar should follow in order to prevent deformation of the Cheddar blocks. Ageing contributes to the development of the desired organoleptic characteristics and to the destruction of contaminating pathogens. The pH value of the fresh product should be 5.2–5.3, otherwise it is possible that the fermentation has failed and the product should be checked for *Salmonella* and *S. aureus*, when ageing is completed after 6–12 months at 4–10°C (ICMSF, 1988). Packages of Cheddar cheese should be stored at refrigerator temperatures and should be kept undamaged and protected from mould growth to extend the shelf life of the product.

3.9.1 Cheddar cheese manufacture

After the milk has been examined for quality and accepted, it is weighed; then a representative sample is taken for determination of fat and casein contents.

The main object of the filtration/clarification step is to remove any visible dirt in milk so as to improve the aesthetic quality of the cheese. The milk is usually preheated to 35–40°C for efficient filtration/clarification.

In cheese making, standardisation refers to adjustment of the casein/fat ratio in cheese milk to 0.68–0.70. The objects are:

(i) to regulate the fat in the dry matter of cheese
(ii) to produce the maximum amount of cheese per kilogram of fat in cheese milk. Standardisation should either be done correctly, or avoided altogether.

The usual temperature–time employed for pasteurisation of cheese milk is: (i) holder –63°C for 30 minutes and (ii) HTST – 71°C for 15 seconds. The objects or advantages of pasteurising cheese milk are: (i) to destroy all pathogens, (ii) to destroy fault-producing micro-organisms, (iii) to produce a more uniform product of high quality and (iv) to increase the yield.

The main limitations of pasteurisation are: (i) it destroys the typical flavour and body of cheese; (ii) it entails a longer ripening period; (iii) it encourages the use of low-quality milk; and (iv) it increases the overall cost of cheese making. The advantages of pasteurisation heavily outweigh its disadvantages.

3.9.2 Homogenisation

The advantages of homogenisation are: (i) lower fat losses in whey and thereby a higher yield of cheese; (ii) reduced fat leakage of cheese at elevated temperatures; and (iii) increased rate of fat hydrolysis in some cheeses, such as blue cheese. The disadvantage is: a softer curd is formed, which necessitates modifications in the cheese-making process. Because of the disadvantage, cheese milk is normally not homogenised.

Excessive heat-treatment causes the precipitation of a part of the calcium salts in milk. This results in slower renneting action and a weaker curd, which can be corrected by the addition of 0.01–0.03% calcium chloride to milk.

Ripening or souring of milk refers to the development of acidity in milk from the time it is received in the cheese vat until renneting. In cheese milk, ripening is done by the addition of starter.

3.9.3 Starter culture

The starter is the 'heart' of cheese. A bad starter is almost certain to produce low-quality cheese. A good starter may make up for other defects, such as contaminated milk. There are different kinds of cheese starters, such as those producing acids, aroma, special effects (such as 'eyes') etc. A Cheddar cheese starter usually contains *Str. lactis* and/or *Str. cremoris*.

The usual time to add the starter is before all the milk has been received in the vat. The amount of starter added is to the extent of 0.5–1% of the milk, and the temperature of addition is 30–31°C. Before being added to the milk, the starter should be examined for its quality; it should then be stirred until smooth and creamy in consistency; then strained and added in the required quantity, and mixed thoroughly and uniformly into the milk.

Ripening (or addition of starter) aids in: (i) the formation of desirable curd; (ii) establishing a favourable bacterial flora (and checking the growth of undesirable micro-organisms); and (iii) controlling moisture. Ripeness in milk is measured by titration (for acidity), rennet test and pH meter.

When a colourant is used, it is added just before renneting. The usual amount is 30–200 mL or more (for buffalo milk) for 1000 kg milk. The colourant is diluted with approximately 20 times its volume of (potable) water for even distribution. It is vigorously agitated to ensure uniform and rapid distribution. The colour of cheese is usually an alkaline solution of annatto. Rennet and colour should not be mixed together before being added to the milk.

3.9.4 Rennet

Adding rennet to milk in cheese making is commonly known as renneting or setting. Rennet is the crude preparation or extract from the abomasum. Rennet contains two principal enzymes: rennin and pepsin. Rennin is an extremely powerful clotting enzyme, which causes rapid clotting without much proteolysis. On the other hand, pepsin induces proteolysis, leading to bitterness in cheese. Rennet is available as a liquid or powder or as tablets.

Rennet is the preparation obtained commercially from the fourth or true stomach (abomasum) of the young calf, known as the vell. The lining of the stomach is washed, dried, cut into small pieces and macerated into water containing about 4% rennet. Alternatively, a brine extract at 15–20°C may be prepared. A common method is to dry the vells by inflation and afterwards cut them into strips and extract with brine, i.e. sodium chloride solution (up to 10%) for a few days. Preservatives such as boric acid are commonly added.

The essential properties of commercial rennet are high activity, stability (constant strength) and a reasonable bacteriological purity. Rennet is commonly supplied in barrels, stone jars or plastic containers. Commercial rennet should be stored in a closed vessel, in a dark room at below 10°C. It should not lose more than 1–2% of its strength per month.

Rennin is a sulphur-containing protein. One part can clot about 5 million parts of milk. In cheese making, one part of liquid rennet (about 2% protein) is used for about 5000 parts of milk. Being an enzyme, it is easily destroyed by heat, many chemical substances and some physical conditions. It is very sensitive to alkali. Heating to 70°C at pH 6.8–7.0 will destroy it in 14 minutes.

Below 20°C, rennin is almost inactive. From 30–48°C, it is almost equally active, the optimum being 41°C. Above 50°C, the activity falls off rapidly. The rate of clotting increases rapidly with small increases in acidity. Alkalis considerably retard the clotting of milk by rennet. Calcium ions have little, if any, effect on the first enzymic stage of rennin action, while the coagulation of milk (second stage) is very sensitive to changes in concentration of calcium ions. It is common practice to add calcium chloride to milk which has been severely pasteurised, e.g. at 80°C for 30 seconds. This acts in three ways, by lowering the pH value, increasing the calcium ion concentration and raising the colloidal calcium phosphate content.

Many colloidal substances interfere with rennin coagulation, e.g. albumin, serum peptone etc. Albumin and globulin retard coagulation. Boiling, resulting in denaturation of the proteins, removes the inhibitory effect. Five per cent 'peptone' almost prevents clotting. Homogenisation has an accelerating effect on rennet clotting, but decreases the curd tension. Heat not only destroys rennin but also makes clotting of the milk by the enzyme less easy. The major reason for this is the removal or precipitation of calcium ions.

Rennet is added when it has been determined that the acid is developing at the desired rate. Thus, when making cheese from ripened milk, rennet is added when the acidity has increased from the initial level by 0.02%. The ideal temperature for setting raw milk under normal conditions is 30°C, and for pasteurised milk, 31°C. The amount of rennet extract used should be such as to form curd that is firm enough to be cut in 25–30 minutes after the addition rennet.

The amount of rennet which should be added depends on the: (i) strength of the rennet, (ii) temperature of the milk, (iii) acidity of the milk and (iv) composition of the milk. Usually, liquid rennet is added 15–25 mL per 100 L of milk. The rennet is diluted with 20–40 times its volume of (potable) water before it is added to ensure proper distribution for uniform coagulation. The milk is thoroughly stirred during the addition of the rennet and also for 3–5 minutes afterwards. The vat is covered as soon as the stirring is over, to keep the surface warm and protect it from contaminating dust particles.

Cutting refers to the cutting of the 'firm' coagulum into cubes of a specific size. When a (sanitised) glass rod is inserted at a 45°C angle and lifted straight up makes a clean break in the curd, it is ready for cutting. If the curd is cut too soon, there will be a lower yield of cheese; if cut too late, cutting will be difficult and moisture expulsion delayed.

3.9.5 Draining

Drainage of whey refers to the removal of whey from the curd. When the curd cubes have been reduced to about one-half of their size at cutting, the acidity approaches a desirable value and the cubes attain a desirable consistency (elastic feel when squeezed), stirring is stopped and the cubes are 'pitched'. The curd cubes

are pushed away from the gate of the vat. In actual practice, especially with large vats, it is quite ready so as to make quick removal of the remaining whey possible at the proper time.

3.9.6 Cheddaring

Cheddaring refers to the combined operations of packing, turning, piling and re-piling the curd cubes. After the bulk drainage of whey, the curd cubes are kept closely together in two heaps with a channel in between. This is known as packing, and takes 5–15 minutes after dipping. It results in the formation of two long slabs of curd. These are cut with a cheese knife into blocks or strips 15–20 minutes wide. As soon as the blocks of curd can be handled without breaking, there are rolled bottom-side up in the vat. This is called turning and is carried out every 15 minutes till the curd is ready for milling and salting. The vat is kept covered and the temperature of the curd maintained at about 32°C. The cheddaring operation usually lasts for two hours or more and is very important not only for moisture control but also for improving body and texture.

3.9.7 Storage

Natural cheeses should be stored at low temperatures, preferably at 0–1°C, to ensure good quality. A high temperature leads to evaporation of moisture, growth of unwanted moulds and taint-producing bacteria, and other faults. A very low temperature also leads to mould growth (because of the relatively high humidity usually associated with it) and may result in damaged texture. Processed cheese may be stored at 5–10°C.

The 'ideal' requirements for high-grade cheddar cheese are:

(i) Colour: uniform, light amber to ivory, not artificially coloured.
(ii) Finish and appearance: smooth, unbroken rind and a neat, clean, attractive appearance.
(iii) Body: slightly elastic, breaks slowly when plug is bent, firm but not hard when crushed between the fingers.
(iv) Texture: compact, continuous and homogeneous, free from openings, holes, breaks, cracks or fissures.
(v) Flavour: clean, pleasing aroma, mildly salted in taste, when fully aged, causes a pleasant tingling sensation within the mouth after cheese is swallowed, leaves pleasing after-taste resembling the flavour of sweet nuts. The defects in cheddar cheese are given in Table 3.32.

3.10 SWISS-TYPE CHEESES (GRUYÈRE AND EMMENTAL)

Gruyère and Emmental are hard or semi-hard cheeses and they are characterised as 'cheese with eyes'. They were originally manufactured in Switzerland, although nowadays they are also produced in considerable quantities in France. The typical composition on these cheeses is (i) Gruyère: moisture 38% and fat in dry matter 49% and (ii) Emmental: moisture 40% and fat in dry matter 45%.

The main differences between these Swiss cheeses are that Emmental has a round shape, a sweet taste and pleasant flavour, and big, thick, and internally shiny eyes, while Gruyère is half the size of Emmental, contains smaller and fewer eyes, and is characterised by intense flavour. The flavour of Gruyère can be attributed to the growth of micro-organisms on its surface and to penetration of their enzymes into the cheese mass, while Emmental is cleaned everyday to minimise the presence of micro-organisms on its surface (Zerfiridis, 1994). The characteristic eye formation in these cheeses is related to propionic acid fermentation and to CO_2 release. Eye formation is a prolonged procedure, which is retarded when the cheese body becomes hard and CO_2 production decreases. The stages of this process have been schematised by Steffen *et al.* (1993) and depend mainly on the following factors: (a) use of proper starter culture, including *Propionibacterium*; (b) timely and adequate production and diffusion of CO_2 and accumulation of CO_2 in uniformly distributed centres; (c) correct adjustment of temperature; and (d) prevention of butyric acid fermentation, due to the activity of *Coliforms*, *Clostridia* and yeasts.

The flow diagram for the manufacture of Swiss cheeses is outlined in Fig. 3.9. Raw milk used for these cheeses should be of premium microbial quality and Clostridia free. Clarification of milk is usually carried out at approximately 30°C, and contributes to the removal of foreign material. The milk should be standardised to a casein/fat ratio of 0.7–0.8 in order to produce cheese of the desired quality. The mixture of starters that is commonly used for Swiss cheeses is (Zerfiridis, 1994): (a) 0.6% *Lactococcus cremori* and *Lactococcus lactis* (active at 32°C), (b) 0.1–0.2% *Streptococcus thermophilus*, which is active at high scalding temperatures, (c) 0.1–0.2% *Lactobacillus helveticus* (high acidity and ripening) and (d) a few drops of *Propionibacterium shermanii* (releases of propionic acid and CO_2).

After rennet addition, the milk should be left undisturbed at 32°C for 30 minutes. Curd formation is critical to the correct manufacture of these cheeses,

Table 3.32 Defects in cheddar cheese, their causes and prevention.

Name of defect	Causes	Prevention
Colour		
Acid cut/bleached/faded	Excessive acid development in cheese curd	Optimum acid development in cheese curd
High/unnatural	Excessive addition of colour to cheese milk	Optimum addition of colour to cheese milk
Mottled	(i) Combining cheese curd from two vat-lots (ii) Uneven acid development in cheese curd	(i) Not combining cheese curd from two vat-lots (ii) Even acid development in cheese curd
Seamy	(i) Incorrect method of addition of salt to curd cubes (ii) Pressing curd cubes too soon after salting	(i) Correct method of addition of salt to curd cubes (ii) Pressing curd cubes with sufficient time-gap after salting
Uneven/wavy	Pressing layers of curd cubes from two different vat-lots	Not pressing layers of curd cubes from two different vat-lots
Finish and appearance		
Cracked paraffin	Excessive thickness of paraffin coating on cheese	Optimum thickness of paraffin coating on cheese
Scaly paraffin	Insufficient thickness of paraffin coating on cheese	Correct thickness of paraffin coating on cheese
Lopsided/misshapen	Incorrect filling and pressing of curd cubes	Correct filling and pressing of curd cubes
Cracked rind	(i) Incorrect cheddaring of cheese curd (ii) Incorrect drying of cheese	(i) Correct cheddaring of cheese curd (ii) Correct drying of cheese
Rind rot	Excessive acidity and/or moisture in cheese before curing	Optimum acidity and/or moisture in cheese before curing
Mouldy surface	(i) Excessive high humidity during curing and storage (ii) Excessive high temperature of curing and storage (iii) Unsanitary conditions of curing and storage rooms (iv) Delayed turning and inspection of cheese blocks during curing and storage	(i) Optimum high humidity during curing and storage (ii) Correct temperature of curing and storage (iii) Sanitary condition of curing and storage rooms (iv) Frequent turning and inspection of cheese blocks during curing and storage
Huffed	Excessive gassy fermentation in cheese	Avoiding gassy contamination in cheese
Body		
Corky/dry/hard	(i) Insufficient fat content in cheese (ii) Excessively slow acid development in cheese curd (iii) Insufficient moisture in cheese before curing	(i) Optimum fat content in cheese (ii) Optimum acid development in cheese curd (iii) Optimum moisture in cheese before curing
Crumbly	Excessive acid development in cheese curd	Optimum acid development in cheese curd
Curdy/rubbery	(i) Low moisture content in cheese before curing (ii) Low acid development in cheese curd (iii) Insufficient cheddaring of cheese curd (iv) Over-salting of cheese (v) Excessively low temperature of curing cheese	(i) Optimum moisture content in cheese before curing (ii) Optimum acid development in cheese curd (iii) Proper cheddaring of cheese curd (iv) Optimum salting of cheese (v) Optimum temperature of curing cheese
Greasy	High-fat content in cheese	Optimum fat content in cheese
Mealy/salvy	Excessive acid development in cheese curd	Optimum acid development in cheese curd
Pasty/watery/wet	Excessive moisture content in cheese	Optimum moisture content in cheese
Weak/soft	(i) High-fat content in cheese (ii) High moisture content in cheese	(i) Optimum fat content in cheese (ii) Optimum moisture content in cheese

Table 3.32 (Continued)

Name of defect	Causes	Prevention
Texture		
Fish eyes/yeast holes	Contamination with yeast	Avoiding contamination with yeast
Pin holes/gassy	Contamination with gas-producing micro-organisms	Avoiding contamination with gas-producing micro-organisms
Mechanical holes (openings)	Incorrect cheddaring of cheese curd	Correct cheddaring of cheese curd
Swiss holes/shot holes	Contamination with propionic *Bacterium shermanii*	Avoiding contamination with propionic *Bacterium shermanii*
Flavour		
High acid/sour	High-acid development in cheese curd	Optimum acid development in cheese curd
Bitter	(i) Low-quality milk (ii) Low-quality starter (iii) Excessive acid and/or moisture in cheese (iv) Unsanitary condition of equipment and surroundings (v) Excessive amount of rennet	(i) Good-quality milk (ii) Good-quality starter (iii) Optimum acid and/or moisture in cheese (iv) Sanitary condition of equipment and surroundings (v) Optimum amount of rennet
Mouldy	(i) Selection of wrong cheese for curing (ii) Adopting warm curing conditions (iii) Unsanitary conditions of curing and storage rooms (iv) Inadequate supervision during curing and storage	(i) Selection of right cheese for curing (ii) Adopting cold curing conditions (iii) Sanitary conditions of curing and storage rooms (iv) Proper supervision during curing and storage

Adapted from De (2000); Mackie and Elsaesser (1991); http://www.dairyscience.info/cheese_model.htm.

because if the temperature is too low and coagulation is prolonged, the curd will become soft and friable, thus resulting in considerable fat losses in whey and many small holes in the final product. On the contrary, if the temperature is too high, the curd will be hard and whey will not be sufficiently released during scalding, leading to cheese blowing. When the curd is firm enough, it should be cut in uniform small cubes, about the size of rice or wheat grains. Different sizes of curd particles promote insufficient or excessive moisture and fat losses in whey degrading the final product. At this point, whey acidity should be 1–2°D higher than half of the milk acidity during rennet addition. Stirring of the curd without heating aims at whey expulsion. Cooking of the curd is carried out in two stages and is crucial to whey expulsion, to the firmness of the cheese mass, and to eye formation. At the beginning, the temperature should slowly rise to 42°C and afterwards faster up to 52°C. Under no circumstances should the temperature reach 56°C because *Propionibacterium* will be killed and fermentation will fail. After cooking, the curd should be intensively stirred in order to avoid precipitation of curd particles. Although stirring usually lasts for 30 minutes, its duration depends on titratable acidity, fat content of milk, curd firmness during cutting, cooking duration and moisture losses from the curd particles.

Once the curd has been placed into hoops, pressure should be gradually applied by means of a screw or a lever press and the pH value should be adjusted to 5.2 or even lower to ensure the completion of lactic acid fermentation, the prevention of undesirable fermentation and the normal course of propionic acid fermentation. Salting is usually performed at 12°C and at a RH of 85–90%. The main difference between the salting of Emmental and the salting of Gruyère is that the brine droplets should be smeared over the surface of Gruyère. The final salt content of Swiss cheeses is relatively low, about 1.5% in order to enhance the growth of *Propionibacterium*, eye formation and flavour development (Steffen *et al*., 1993). After salting, cheeses are transferred into the warm room, where higher temperatures of about 18°C activate *Propionibacterium* allowing eye formation. When the cheese mass swells slightly, cheeses should be transferred back to the cold chamber of 12°C. Both the rates of lipolysis and proteolysis are maximised; thanks to the activity of *Propionibacterium* and the production of proper enzymes. Ripening of Swiss cheeses is usually completed within 3–6 months and it is greatly influenced by water activity (a_w), which varies between 5.75 and 5.95 and

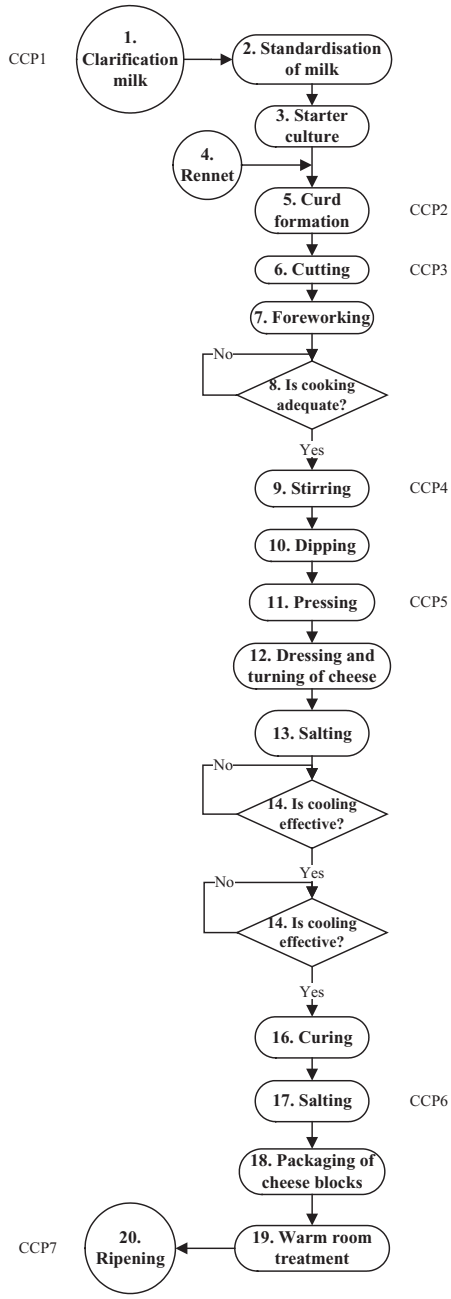

Fig. 3.9 Swiss-type cheeses manufacturing flow diagram.

cheeses should be cold-stored to prevent any further fermentation. Coating the surface of Emmental cheese with wax after ripening is characteristic of this cheese and is not applicable to Gruyère cheese. The determination of CCPs for Swiss-type cheeses is given in Table 3.33.

3.11 CAMEMBERT CHEESE

Camembert cheese was first manufactured in France in 1791 and is characterised by the presence of multicoloured mould and yeast areas on its surface. The typical composition of Camembert cheese found commercially is 50% moisture content, 28% fat content, and 2% salt and minerals. Ideal Camembert cheese should have an attractive aroma, mild and sweet flavour, medium-soft mellowy body, and reddish-yellow colour interspersed with blue-grey patches (Wilster, 1997). To ensure the safe contamination with pathogens, especially *E. coli* and *Listeria monocytogenes*, during ripening and distribution, the pH value of the end product should be risen to 6 or even higher. Temperature and relative humidity controls in the dairy plant are essential throughout the manufacturing process. Moreover, excessive acidity development during draining is undesirable and the moisture content of Camembert cheese should reach the predetermined level to enhance growth of superficial microflora, which is important to the successful manufacture of this cheese.

The flow diagram for the production of Camembert cheese is shown in Fig. 3.10. Raw milk should be standardised to a casein/fat ratio of 0.7, in order to meet the legal requirements for its composition and to prevent potential failures of its texture. Then, milk should be pasteurised and cooled down to 34°C prior to the addition of 2% of the active lactic culture. Use of colourings, in particular β-carotene or annatto, is optional and should be carried out with care. When titratable acidity of the milk has increased to 0.2–0.22%, rennet should be added and left for 90 minutes until curd formation is completed. Cutting, cooking and dipping of the curd should comply with the requirements already described for cheese, altering only the technological conditions under which they are performed. The cooking temperature should not exceed 34°C and dipping should be carried out by breaking the curd, by leaving the curd undamaged, or by dipping a mixture of curd and whey into the moulds. Draining of the curd should be performed at 21°C and at 85–90% RH. The pH value of the final whey should be 5.5, and after that the cheese mass becomes pliable and strong curds should be placed into a cane-bottom container or open board, both of which are favourable to the development of Camembert mould.

Prior to mould spore inoculation, the cheese should be dry-salted on all parts of its surface in order to control the growth of undesirable micro-organisms, to enhance the development of the desired Camembert mould, and to help rind formation by removing moisture from the cheese surface. If salting is delayed and the temperature is raised, growth of *Geotrichum*

Table 3.33 Determination of critical control points (CCPs) for Swiss-type cheeses (Gruyère and Emmental).

S/N	Processing step	Hazard	Description of hazards	Q1	Preventive action	Q2	Q3	Q4	α/α CCP
1	Milk receipt	Biological	Milk with high microbial load	Yes	Periodical control of milk sample	No	Yes	Yes	**CCP1a**
				Yes	Determination of pH	Yes			**1b**
			Distribution under non-hygienic conditions	Yes	Control of temperature of receipt and cleaning of the vehicle	Yes			**1c** **1d**
		Physical	Foreign matter, hair and other material	Yes	Filtration, macroscopic control	No	Yes	Yes	
		Chemical	Antibiotics, pesticide residues	Yes	Periodical control of milk for antibiotic residues	No	Yes	No	
			Adulterated milk (with water or cheaper milk)		Determination of specific gravity	Yes			
					Instructions to producers and sign of agreements for standard specifications (TPC, somatic cells, antibiotics, fat concentration)				
3	Addition of starter	Biological	Whey loaded with micro-organisms, low yield	Yes	Acidity control, use of fresh whey	No	Yes	Yes	**CCP2**
		Physical	Stay of cheese crumbs, burning during pasteurisation	Yes	Filtration	No	Yes	Yes	
4, 5	Rennet Curd formation	Physical	Presence of foreign matter	Yes	Macroscopic control before use	No	Yes	Yes	
		Chemical	Presence of heavy metals	Yes	Reliable suppliers, raw materials	No	No		
		Biological	Slow growth of "good" micro-organisms, prevailing of undesirable and harmful ones	Yes	conforming to the legislation	Yes			
					Weigh rennet				
					Monitoring of temperature of cheese boiler				
					Monitoring of curdling time				
					Control of milk temperature				
6	Cutting	Biological/ physical	Contamination from equipment and personnel, uneven pieces, uneven draining	Yes	Regular cleaning and disinfection, GMPs	No	Yes	Yes	**CCP3**
8	Cooking	Biological	Growth of micro-organisms	Yes	Temperature control of cooking	Yes	Yes	Yes	
			Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No			
10	Stirring	Biological/ physical	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No	Yes	No	**CCP4**
		Biological	Inability to remove moisture, prevailing of good micro-organisms	Yes	Control of room's conditions	Yes			

(*Continues*)

Table 3.33 (Continued)

S/N	Processing step	Hazard	Description of hazards	Q1	Preventive action	Q2	Q3	Q4	α/α CCP
11	Pressing	Biological/ physical	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No	Yes	Yes	**CCP5**
			Unable to remove the required quantity of whey	Yes	Use of appropriate weights, adjustment of room temperature	No	No		
13	Salting	Biological/ physical	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No No	Yes No	Yes	
			Growth of undesirable micro-organisms, not enough quantity of salt	Yes	Adjustment of room temperature				
14, 15, 19	Cool/warm room treatment	Biological	Growth of micro-organisms	Yes	Temperature control of cooling chambers	Yes			
			Release before the end of ripening	Yes	Control of pH, production dates				
18	Salting	Biological	Growth of micro-organisms	Yes	Temperature control of cooling chambers	Yes			**CCP6**
			Release before the end of ripening	Yes	Control of pH, production dates				
20	Ripening	Biological	Contamination from equipment and personnel	Yes	Regular cleaning and disinfection, GMPs	No	Yes	Yes	**CCP7**

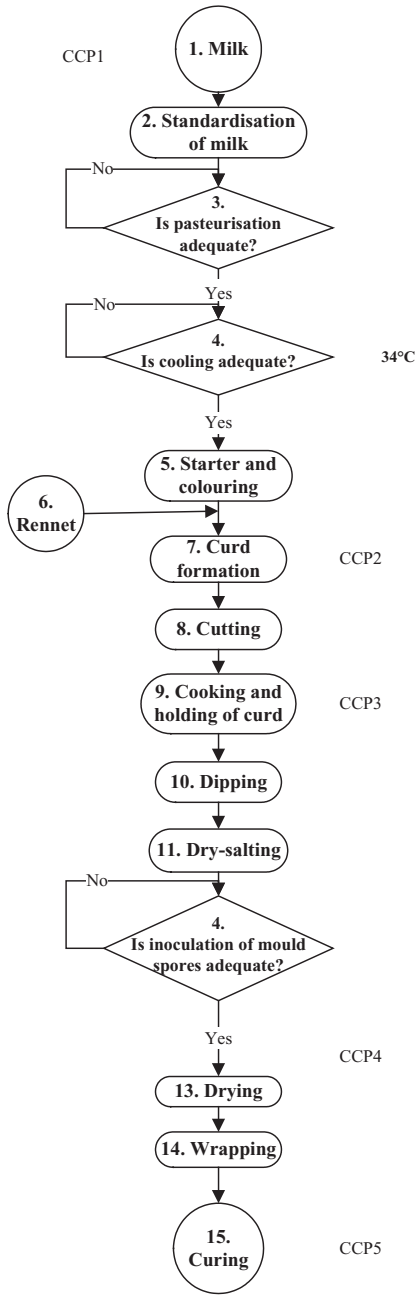

Fig. 3.10 Camembert cheese manufacturing flow diagram.

candidum can be enhanced thus causing flavour deterioration. An effective method to inoculate the cheese with *Penicillium camemberti* spores is by spraying the cheese daily with a water mould culture by means of an atomiser. Mould spores should be obtained from reputable suppliers at regular intervals and should be kept under proper conditions. The required time to spread the slime over the cheese surface is usually two weeks and depends mainly on the manufacturing process and temperature. Ripening of Camembert cheese is crucial to the development of the desired flavour, texture and appearance. Ripening should be performed at 10°C and relative humidity that varies according to the moisture content of cheese and to the ripening stage, in order to create favourable conditions for the growth of *P. camemberti*. As ripening proceeds, Camembert's appearance should become greasy and yeasty. The temperature of the ripening chamber should be gradually lowered. After two weeks, the cheese is usually placed into tin foil to maintain the shape of the cheese and conceal potential cheese imperfections. Before wrapping the cheese, it should be ensured that it is dry enough, otherwise whey will be released and the Camembert may develop an undesired flavour and appearance. The wrapped cheese can be placed into chambers of higher temperature than the ripening chamber, since fermentation continues more rapidly and the mould becomes inactive. The enzymes produced by *P. camemberti* play an important role in further cheese ripening and development of Camembert characteristics. The determination of CCPs for Camembert cheese is given in Table 3.34.

3.12 RISK ASSESSMENT – HACCP

Risk assessment is defined as 'a process of evaluation including the identification of the attendant uncertainties, of the likelihood and severity of an adverse effect(s)/event(s) occurring to man or the environment following exposure under defined conditions to a risk source(s)' (EC, 2000). Risk assessment consists of hazard identification, hazard characterisation, exposure assessment and risk characterisation (Notermans *et al.*, 1996).

Risk assessment of food products has been interwoven with risk analysis system and HACCP. The HACCP system refers to physical, chemical and microbiological hazards occurring in raw materials/processes of food production (Mortimore and Wallace, 1995). However, some hazards or risks may escape from the HACCP system because this risk covers a wider range than that of the food product process. Such an example is the risk of a characteristic that does not have an obvious relationship with physical, chemical and microbiological hazards. This risk mainly refers to the acceptance of the product by the public, particularly negatively predisposed towards GMOs. Its assessment could be part of the recently introduced

Table 3.34 Determination of critical control points (CCPs) for Camembert cheese

S/N	Processing step	Hazard	Description of hazards	Q1	Preventive action	Q2	Q3	Q4	α/α CCP
1	Milk receipt	Biological	Milk with high microbial load	Yes	Periodical control of milk sample	No	Yes	Yes	**CCP1a**
				Yes	Determination of pH	Yes			**1b**
			Distribution under non-hygienic conditions	Yes	Control of temperature of receipt and cleaning of the vehicle	Yes			**1c** **1d**
		Physical	Foreign matter, hair and other material	Yes	Filtration, macroscopic control	No	Yes	Yes	
					Periodical control of milk for	No	Yes	No	
		Chemical	Antibiotics, pesticide residues	Yes	antibiotic residues				
			Adulterated milk (with water or cheaper milk)		Determination of specific gravity	Yes			
					Instructions to producers and sign of agreements for standard specifications (TPC, somatic cells, antibiotics, fat concentration)				
3	Pasteurisation	Biological	Survival of pathogenic micro-organisms, weakness of satisfactory reduction of the initial microbial load	Yes	Control of time and temperature of pasteurisation	Yes			**CCP1**
5	Starter	Biological	Whey loaded with micro-organisms, low yield	Yes	Acidity control, use of fresh whey	No	Yes	Yes	**CCP2**
		Physical	Stay of cheese crumbs, burning during pasteurisation	Yes	Filtration	No	Yes	Yes	
6, 7	Rennet	Physical	Presence of foreign matter	Yes	Macroscopic control before use	No	Yes	Yes	**CCP3**
	Curd formation	Chemical	Presence of heavy metals	Yes	Reliable suppliers, raw materials	No	No		
		Biological	Slow growth of "good" micro-organisms, prevailing of undesirable and harmful ones	Yes	conforming to the legislation	Yes			
					Weigh rennet				
					Monitoring of temperature of cheese boiler				
					Monitoring of curdling time				
					Control of milk temperature				
8	Cutting	Biological/ physical	Contamination from equipment and personnel, uneven pieces, uneven draining	Yes	Regular cleaning and disinfection, GMPs	No	Yes	Yes	

9	Cooking	Biological	Growth of micro-organisms Contamination from equipment and personnel	Yes Yes	Temperature control of cooking Regular cleaning and disinfection, GMPs	Yes No	Yes	Yes	**CCP4**
10	Dipping	Biological/ physical Biological	Contamination from equipment and personnel Inability to remove moisture, prevailing of good micro-organisms	Yes Yes	Regular cleaning and disinfection, GMPs Control of room's conditions	No Yes	Yes	No	
11, 13	Dry-salting	Biological/ physical	Contamination from equipment and personnel Growth of undesirable micro-organisms, insufficient quantity of salt	Yes Yes	Regular cleaning and disinfection, GMPs Adjustment of room temperature	No No	Yes No	Yes	
14	Wrapping	Biological	Growth of micro-organisms Release before the end of ripening	Yes Yes	Temperature control of cooling chambers Control of pH, production dates	Yes			**CCP5**
15	Storage	Biological	Growth of micro-organisms Release before the end of ripening	Yes Yes	Temperature control of cooling chambers Control of pH, production dates	Yes			**CCP6**

ISO 22000 but could not be included in the processes of the HACCP system. The supplementary operations are summarised in Table 3.35 and a synoptical HACCP monitoring system for dairy products is given in Table 3.36. In Table 3.37 (Feta cheese, Batzos and Telemes), Table 3.38 (Kasseri and semi-hard cheese), Table 3.39 (Graviera, hard cheese and Kefalotyri), Table 3.40 (Mizithra, Anthotyros and Manouri), Table 3.41 (Provolone, Romano and Parmesan), Table 3.42 (Cheddar cheese), Table 3.43 (Gruyère and Emmental) and Table 3.44 (Camembert cheese) are given ISO 22000 analysis worksheets for the determination of prerequisite programmes. The prerequisite programmes are also summarised in Table 3.45.

The production of safe food is based on the use of good-quality raw materials and the application of GMP and the HACCP system. In addition, risk analysis is becoming the new cornerstone in producing acceptable, safe food. According to the agreements of the World Trade Organization (WTO), especially the agreement on the application of sanitary and phytosanitary measures – the SPS agreement, the setting of control criteria should have a scientific basis. For this purpose, quantitative risk analysis is considered to be a logical approach that can provide the necessary insight into the process of setting such criteria.

Elements of quantitative risk analysis can also be introduced into the HACCP system, for example, in setting criteria at CCPs (Notermans and Mead, 1996). Notermans *et al*. (1998) outlined a risk assessment approach to food safety evaluation, based on testing a particular type of food, the risk assessment of *Bacillus cereus* in pasteurised milk. The results obtained are related to possible adverse effects on the health of consumers. This chapter also gave an example of the way the risk assessment approach may be used in practice. The proposed system seemed to provide information on the exposure of consumers to microbial pathogens when the food is consumed. It reflected the successful application of GMPs and HACCP principles on the part of the producer; as well as the effect of consumer handling of the product, on the exposure rate. The information obtained on factors affecting exposure to microbial hazards and their impact on consumers would allow risk management and communication to be carried out effectively.

Henson and Holt (1999) explored incentives for the adoption of food safety controls by businesses in the UK dairy sector. Four key factors were found to have motivated the adoption of HACCP and these were internal efficiency, commercial pressure, external requirements and good practice. Four clusters were identified and were related to firm size and type of manufactured products.

Consumer concern about livestock production methodologies has increased over recent decades due to various outbreaks of foodborne zoonoses and animal diseases. Quality assurance programmes in the different production chains have been installed by industry to counteract the problems occurring. The primary producers, like the dairy farms, are not formally comprised in such programmes. Yet, quality control at dairy farm level goes beyond the quality control of the product milk alone (Noordhuizen and Metz, 2005). For better safeguarding of food safety and public health, as well as animal health and welfare, the whole production process on the dairy farm should be addressed. Health and welfare were addressed, while the approach of the Dutch dairy sector was used as an example.

A well-known welfare report regards the Tierges und Heits Index (Animal Health Index), TGI, applied in Germany and Austria, mostly in organic farms. The TGI addresses categories like movement possibilities, opportunities for social contacts, floor design of housing facilities, climatic conditions in the barns and intensity of care by the farmer. Disadvantage of an index is that good categories may cover up for deficient categories. The TGI has features which are comparable to those in good farming practice codes; hence, TGI might be called a good welfare practice code. The emphasis in welfare monitoring in general is on deviant animals as well as on risky environmental conditions on the farm (Von Borell, 2000).

In the case of cattle welfare, the focus should be on those areas which contribute significantly to the occurrence of welfare disorders. Examples are housing (space per cow, floor design for locomotion, cubicle design for resting and lying, maintenance standards, space for social interaction), barn climate (humidity, temperature, ventilation, draughts), feed and water availability, ration composition and quality of feedstuffs.

Therefore, any inspection focusing on welfare issues should address both the animals and the risk conditions in the cow's environment. In addition, several countries have started with the stepwise implementation of, either voluntary or compulsory, quality control programmes on dairy farms. Monitoring of cows (prevalence and incidences) and farm conditions (risk factors) is part of the Dairy Chain Quality programme (KKM) in the Netherlands. The information gathered is currently also used for on-farm consultancies by the veterinary practitioners in herd health programmes. It can be expected that the KKM programme will

Table 3.35 Supplementary operations.

No.	Processing stage	Description of possible dangers	Preventive action	Controls	Critical limits	Responsible	Corrective action	Records
SSM1	General control of water	Contamination or spoilage of water quality Excess chlorine concentration	Microbiological analysis once per 2 months and physicochemical results once per year	Microbiological and chemical analysis of water every 2 months	Characterisation of water as potable according to the legislation (98/83/EC)	Production supervisor External approved lab	Stop service Demand for water rechlorination and check	Lab control
SSM2	General hygienic conditions in the dairy industry	Contamination of product from insects and mice or other pests Contamination due to inadequate hygienic conditions of production areas, equipment and personnel Contamination of product from chemical materials used in the production area Product contamination from infectious diseases carried by personnel	According to Reg. 852/2004, GMP principles Personnel training Implementation of working instruction 'Cleaning, disinfection, pest control' Issue of valid health books	Continuous control of hygienic conditions of places, equipment, personnel and programme for pest control Weekly audits of places and personnel Swab test, residue control using phenolphthalein indicators once a month Health books	According to Reg. 852/2004 Disinfection Negative test for indicator Absence of skin, gastroenteric and respiratory diseases	Production supervisor Cleaning operator Production supervisor	Direct withdrawal of every non-conformance Repetition of personnel training Full recovery of sick personnel Repetition of disinfection	Cleaning and disinfection Weekly audit of places, installation and equipment Programme of cleaning and disinfection Personnel records
SSM3	Keeping of working instructions by personnel	Cross-contamination Transfer of foreign matter	GMP implementation Hand washing Cleaning of gloves and overalls	Control every hour during work	Absolute conformance	Production supervisor	Direct withdrawal of every non-conformance	

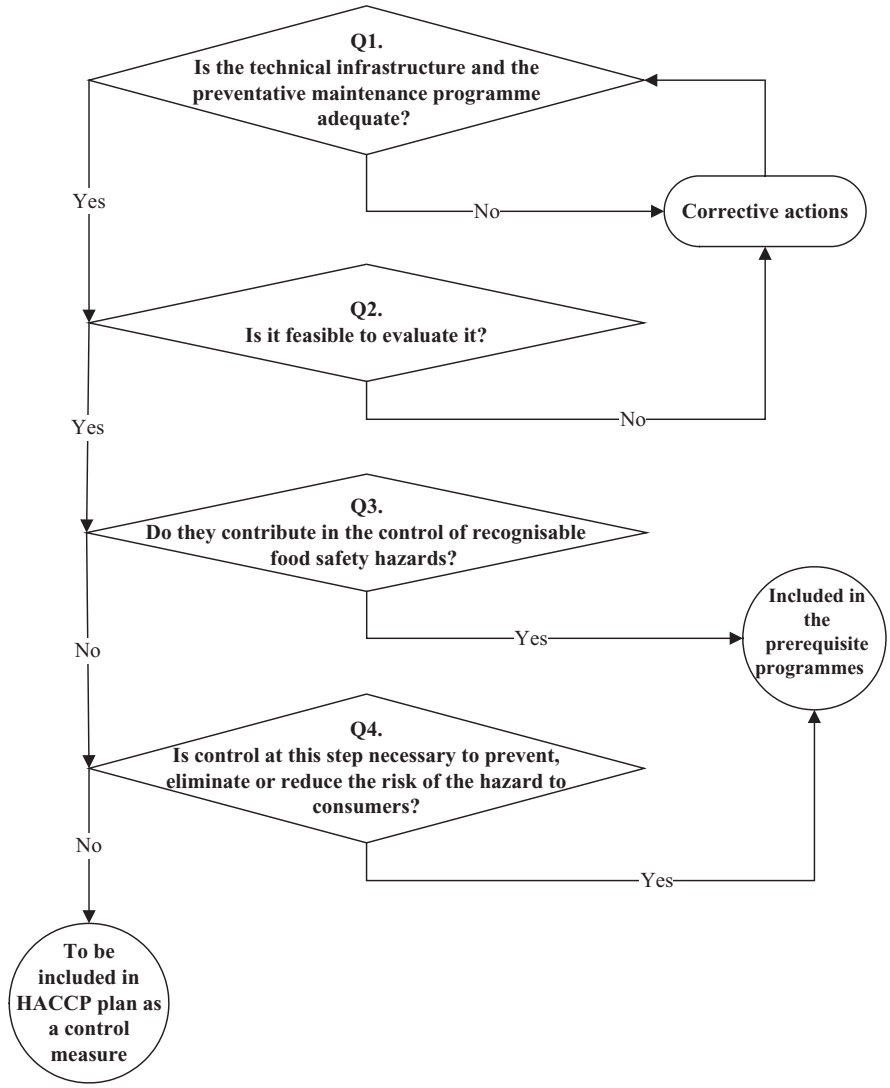

Fig. 3.11 Recognition of prerequisite programmes.

ultimately result in a HACCP-based quality management programme including good farming practice codes, where risk identification, risk management and prevention will play a paramount role.

Noordhuizen and Metz (2005) concluded that based on developments within the dairy sector as well as at the EU political level, it can be expected that the application of HACCP-compatible programmes on the dairy farms will be conducted in the near future. This application will help in identifying and managing the quality hazards and risks occurring in the production process on dairy farms, and in providing the consumer with more certainty about the quality of products of animal origin.

3.13 HYGIENE MONITORING AND PREREQUISITE PROGRAMMES

In a typical dairy operation, relative light unit (RLU) data, reflecting the ATP bioluminescence technique for rapid hygiene testing, were collected over a period of three months from a control point (CP) of a milk filling machine and analysed in retrospect (Hayes *et al.*,

Table 3.36 Synoptical HACCP monitoring system for reprentating cheese and dairy products.

Product	Processing stage	Description of possible dangers	Controls	Critical limits	Responsible	Corrective action	Records
All products	Milk receipt	Milk with high microbial load Milk contaminated with pathogenic micro-organisms Transportation under non-hygienic conditions Antibiotics Adulterated milk (with water or cheaper milk)	Determination of pH Control of receipt temperature and cleaning of transportation vehicle Antibiotics kits Specific gravity	6.4–6.6 T < 7°C According to legislation 1.029–1.045 in 15°C	Receipts supervisor	Return of non-conforming lot Recommendations to suppliers	Non-conformance sheet, corrective and preventive action Non-conforming book Incoming materials sheet
	Curd formation	Slow growth of "good" micro-organisms in starter cultures, prevailing of harmful micro-organisms	Weigh quantity of rennet Monitoring of temperature of cheese boiler Monitoring of curding time Control of milk temperature	According to milk condition and type of cheese approximately 32–33°C Rennet according to instructions of use Entrance temperature in the boiler of 32°C	Production supervisor	Increase or decrease temperature of cheese making and milk Increase or decrease quantity of rennet based on experience	Production log
Feta/Batzos/ Telemes	Brine formation	Low strength Low strength of antimicrobial action	Salt content	pH when the cheese curd gets into brine of approximately 6.2 16°Bé	Production supervisor	Addition of extra salt	Production log
	Dry-salting/ ripening in cheese tables and in open containers	Failure to increase salt coefficient Drop in pH and moisture removal Immature stop of fermentation	pH monitoring Control of room temperature	At the end of salting (1 day cheese) pH <5.2 At the end of prematuration (before entrance to the fridge) pH <4.8 Minimum 16°C	Production supervisor	Extension of ripening outside the fridge Adaptation of expiry date/fast distribution and consumption 2 months after in the fridges Air conditioning	Production log

(*Continues*)

Table 3.36 (Continued)

Product	Processing stage	Description of possible dangers	Controls	Critical limits	Responsible	Corrective action	Records
Kasseri	Cutting/ immersion/ fermentation	Failure to kill micro-organisms	Control of temperature of hot water, time	Minimum 70°C/15 minutes	Production supervisor	Adjustment of temperature, time extension	Production log
	Salting/ ripening	Failure to remove moisture Growth of undesirable micro-organisms	Control and adjustment of temperature and moisture in the maturation chamber	15–16°C RH = 80–90%	Production supervisor	Air conditioning/ adjustment of temperature	Production log
Graviera/ Kefalotyri	Pressing/ change of paddy/ reversing	Failure to remove moisture, prevailing of good micro-organisms	Control of room temperature conditions	15–16°C End of pressing pH <4.8	Production supervisor	Air conditioning/ adjustment of temperature	Production log
	Brine formation	Weak brine/ weakness of antimicrobial action	Salt content	Minimum 16°Bé	Production supervisor	Addition of extra salt	Production log
	Ripening	Failure to remove moisture Growth of undesirable micro-organisms	Control and adjustment of temperature and moisture in the maturation chamber	Graviera: 2 weeks at 12–14°C, 4 weeks at 18°C, 6 weeks at 12–14°C RH = 85% Kefalotyri: 3 months at 12–16°C RH = 85%	Production supervisor	Airconditioning/ adjustment of temperature	Production log
Mizithra/ Manouri/ Anthotyros	Receipt of whey/ filtration	Remaining of cheese crumbs, burning during thermal processing	Macroscopic control of raw materials Control of pH	pH >6.3 No visible piece	Production supervisor	Addition of NaOH Rejection Refiltration	Production log
	Pasteurisation	Survival of pathogenic micro-organisms, weakness to reduce the initial microbial load satisfactorily	Temperature and time control	Increase from 30 to 75°C in 30 minutes and from 75 to 90°C in 15 minutes Total thermal processing time is 45 minutes	Production supervisor	Extension of pasteurisation/ adjustment of temperature	Production log

	Packaging	Vacuum failure, hermetic sealing, growth of micro-organisms	Control of parameters of device, sealing control	Hermetic sealing No non-conformance	Production supervisor	Repetition	Production log
Butter	Pasteurisation	Survival of pathogenic micro-organisms, Unsatisfactory reduction of microbial load	Control of temperature and time	63°C/30 minutes	Production supervisor	Extension of pasteurisation/ adjustment of temperature	Production log
Provolone/ Romano/ Parmesan	Starter culture	Weakness to start the culture	Control of temperature Control of acidity	82°C/30 minutes Acidity 0.8%	Production supervisor	Adjustment of temperature	Production log
	Pressing	Failure to control the pressure	Control the pressure	69 kPa/30 minutes at room temperature 138 kPa overnights	Production supervisor	Increase of pressure/ repetition	Production log
Cheddar cheese	Heating	Growth of undesirable micro-organisms	Control of temperature	38°C pH = 6.0–6.1	Production supervisor	Adjustment of temperature	Production log
Gruyère/ Emmental	Cooking	Growth of undesirable micro-organisms Destroy of useful micro-organisms for ripening	Control of temperature	Rising slowly from 42–52°C for 30 minutes Avoiding ≥56°C	Production supervisor	Adjustment of temperature	Production log
	Salting	Failure to remove moisture Growth of undesirable micro-organisms	Control and adjustment of temperature and moisture	pH = 5.2 12°C RH = 85–90%	Production supervisor	Adjustment of temperature/ humidity	Production log
Camembert cheese	Draining	Failure to remove moisture Growth of undesirable micro-organisms	Control and adjustment of temperature and moisture	pH = 5.5 21°C RH = 85–90%	Production supervisor	Adjustment of temperature/ humidity	Production log

(*Continues*)

Table 3.36 (Continued)

Product	Processing stage	Description of possible dangers	Controls	Critical limits	Responsible	Corrective action	Records
All products	Cooling	Growth of undesirable micro-organisms Release before the end of ripening	Control of temperature of refrigeration chambers Control of date of entrance/ exit Periodical checks of the final product in an external lab	0–4°C RH = 85–95% Depending on product and legislation	Production supervisor	Adjustment of temperature/ humidity Repairing of malfunction Rejection 1st distribution/ adaptation of shelf life	Temperature recording meters Lab control results
	Distribution	Growth of undesirable micro-organisms	Temperature control of the cooling chambers in the vehicles	0–4 °C	Driver	Adjustment of temperature/ repairing of malfunction Reject	Recording meters

Table 3.37 ISO 22000 analysis worksheet for the determination of prerequisite programmes for Feta cheese/ Batzos/Telemes.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Water	Yes	Yes	No	Yes	Yes
Milk receipt	Yes	Yes	No	No	No
Receipt of other raw materials	Yes	Yes	No	Yes	Yes
Salt Starter cultures Rennet					
Receipt–storage of packaging materials	Yes	Yes	No	Yes	Yes
Pasteurisation	Yes	Yes	No	Yes	Yes
Starter culture preparation	Yes	Yes	No	Yes	Yes
Brine formation	Yes	Yes	No	No	No
Curd formation	Yes	Yes	No	No	No
Curd cut–moulding	Yes	Yes	No	Yes	Yes
Dry-salting/ripening in cheese tables and in open containers	Yes	Yes	No	No	No
Cooling	Yes	Yes	No	No	No
Distribution	Yes	Yes	No	No	No

1997) to assess the hygiene status of various CPs in any HACCP system. The measurement in RLU is used to give a pass/fail status to the CP tested.

The analysis showed that the Cusum and Individual charts established a proper trend analysis of the RLU data. Advance warning signs signifying potential out of control (fail) and CP status were clearly shown in the charts. The findings highlighted the fact that by employing statistical process control (SPC) tools, it was possible to prevent CPs from failing the hygiene test. Furthermore, if the SPC technique of identifying assignable and unassignable causes of failure was adopted, the total number of failed CPs should decrease. This would, in the long run, lead to more effective hygiene management and more efficient production.

Moreover, Bactoscan analysis and ATP could be applied as emergency brakes by food firms as explained by Giffel *et al*. (2001). They reported that the main problem is the sensitivity of the techniques. In the future, process control systems can be developed by integrating microbiological results and predictive models into process control software. IT, neural networks and fuzzy logic could help in this direction.

In practice, the fuzzy logic allows computing with words – fuzzification. The architecture of the food system is codified through 'fuzzy' cognitive maps by allowing the conversion of stimuli to responses attributive, so that they translate mathematically the appropriate actions for sanitary hygienic control.

Those abaci are the 'fuzzy numbers' that translate the criteria of HACCP, for instance, the levels of contamination risks at different stages of the productive process. Fuzzy logic does not require an analysis of hazards as in HACCPs, because it spares the determination of sample sizes based on the presuppositions of the statistical inference. The fuzzy logic bases on the postulates of the theory of possibility, where there is not a necessity to assist the axioms of probability, such as no negativity and unity (Braga *et al*., 1995).

The results reached by the application of the method of analysis based on fuzzy logic for the CCPs revealed that none of the schools of the sample got to reach the hygienic–sanitary quality pattern according to the rules of gold of the 'OMS'. The methodology revealed rates lower than 0.35; an exception was the item stocking in one of the full-time-type schools, which reached quality pertinence of 0.72. Food processing designs to comply with the desired sanitary–hygienic patterns must have quality pertinence levels higher than 0.70 in all macro-events.

The results lead to the conclusion that the employment of 'fuzzy cognitive maps' is feasible and can be a facilitating alternative technique, mainly in samples of

Table 3.38 ISO 22000 analysis worksheet for the determination of prerequisite programmes for Kasseri/semi-hard cheese

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Water	Yes	Yes	No	Yes	Yes
Milk receipt	Yes	Yes	No	No	No
Receipt of other raw materials	Yes	Yes	No	Yes	Yes
Salt Starter cultures Calcium chloride Receipt–storage of packaging materials	Yes	Yes	No	Yes	Yes
Pasteurisation	Yes	Yes	No	Yes	Yes
Curd formation	Yes	Yes	No	No	No
Curd cut–moulding	Yes	Yes	No	Yes	Yes
Stirring/reheating/ precipitation	Yes	Yes	No	Yes	Yes
Curd removal/curd extraction	Yes	Yes	No	Yes	Yes
Cutting/mixing	Yes	Yes	No	Yes	Yes
Pressing of cheese mass	Yes	Yes	No	Yes	Yes
Ripening of cheese mass	Yes	Yes	No	No	No
Cutting/immersion in hot water/fermentation	Yes	Yes	No	No	No
Moulding/hardening of cheese heads	Yes	Yes	No	Yes	Yes
Mould removal	Yes	Yes	No	Yes	Yes
Salting/ripening	Yes	Yes	No	No	No
Drying	Yes	Yes	No	Yes	Yes
Paraffin/packaging	Yes	Yes	No	Yes	Yes
Cooling	Yes	Yes	No	No	No
Distribution	Yes	Yes	No	No	No

reduced dimensions. The fuzzy method has been applied in quality control, when the parameters used do not allow rigid limits. This is the peculiar case of the controls in the hot and cold chains in collective feeding. The abaci fuzzy are easy and agile instruments to evaluate the conditions of temperature of the food supply and to determine the quality of the productive process.

Attitudes towards food hygiene management strategies in their companies were measured by a mail survey designed and distributed to 87 Finnish food manufacturing companies in order to be distributed to 870 employees representing both workers and managers by Hielm *et al.* (2006). The final response rates for companies and individual employees were 34.9 and 21.2%, respectively. Answers were stratified according to four job categories and four industry sectors (meat, dairy, fish and bakery). The employees' attitudes towards various surveyed risk management practices were exclusively positive, regardless of job category or industry sector. All 30 companies that responded to the survey had a functioning own-checking plan (OCP), while other quality management programmes were less prevalent. When asked what had caused most difficulties in devising the OCP/HACCP plan, the most common answers were choosing the CCPs, committing the firm's entire workforce and organising the documentation of monitoring results. According to the respondents, the biggest benefits of the OCP/HACCP plan were product safety and quality.

In Finland, as in the other Nordic countries, the preventive risk management strategy in the food industry is based on good hygiene practices (GHPs or hygiene prerequisites) and HACCP plans when appropriate.

Table 3.39 ISO 22000 analysis worksheet for the determination of prerequisite programmes for Graviera/hard cheese/Kefalotyri.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Water	Yes	Yes	No	Yes	Yes
Milk receipt	Yes	Yes	No	No	No
Receipt of other raw materials	Yes	Yes	No	Yes	Yes
Salt Rennet					
Receipt–storage of packaging materials	Yes	Yes	No	Yes	Yes
Brine formation	Yes	Yes	No	No	No
Pasteurisation	Yes	Yes	No	Yes	Yes
Curd formation	Yes	Yes	No	No	No
Curd cut–moulding	Yes	Yes	No	Yes	Yes
Stirring/reheating/ precipitation	Yes	Yes	No	Yes	Yes
Curd removal/curd extraction	Yes	Yes	No	Yes	Yes
Moulding	Yes	Yes	No	Yes	Yes
Pressing/change of paddy/reversing	Yes	Yes	No	No	No
Mould removal/ placement in brine	Yes	Yes	No	Yes	Yes
Dry-salting/surface abrasion	Yes	Yes	No	Yes	Yes
Ripening	Yes	Yes	No	No	No
Washing/drying	Yes	Yes	No	Yes	Yes
Paraffin formation/ packaging	Yes	Yes	No	Yes	Yes
Cooling	Yes	Yes	No	No	No
Distribution	Yes	Yes	No	No	No

This approach, termed own-checking, became mandatory for Finnish food operators, caterers and retailers in 1995.

Because of difficulties in implementing HACCP, the hygiene prerequisites have until now formed a substantial part of the own-checking system in Finland. Panisello and Quantick (2001) have categorised requirements for successful HACCP implementation into four 'segments': management commitment, education and training, availability of resources and external pressures; shortcomings are explained by three 'technical barriers' (1) prior to, (2) during the process of and (3) after HACCP implementation. The technical barriers seem a far more formidable hurdle to overcome, as these encompass all those practices, attitudes and perceptions that negatively affect the understanding and proper and effective implementation of the HACCP principles (Panisello and Quantick, 2001). Recent behavioural studies from the United Kingdom (Taylor and Taylor, 2004), Italy (Angelillo *et al.*, 2001), the United States (Henroid and Sneed, 2004), Poland (Konecka-Matyjek *et al.*, 2005) and the Philippines (Azanza and Zamora-Luna, 2005) assert that such barriers are of a universal nature.

Although own-checking/HACCP is in widespread use in the EU, few surveys have been published on attitudes towards the systems among food company employees, such as a UK survey polling attitudes among food business managers towards food hygiene practices and HACCP, in which the authors found that positive attitudes towards HACCP correlated significantly with company size and previously received

Table 3.40 ISO 22000 analysis worksheet for the determination of prerequisite programmes for Mizithra/Anthotyros/Manouri.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Milk receipt	Yes	Yes	No	No	No
Receipt of whey/ filtration	Yes	Yes	No	No	No
Salt	Yes	Yes	No	Yes	Yes
Receipt–storage of packaging materials	Yes	Yes	No	Yes	Yes
Pasteurisation/baking of cheese curd	Yes	Yes	No	No	No
Collection/moulding	Yes	Yes	No	Yes	Yes
Straining	Yes	Yes	No	Yes	Yes
Mould removal	Yes	Yes	No	Yes	Yes
Stay on the cheese table	Yes	Yes	No	Yes	Yes
Packaging	Yes	Yes	No	No	No
Cooling	Yes	Yes	No	No	No
Distribution	Yes	Yes	No	No	No

training on HACCP (Mortlock *et al*., 1999). Also in the UK, Panisello *et al*. (1999) surveyed food companies to establish the level of, and barriers to, HACCP implementation. While HACCP was implemented in 73% of the responding companies, the authors recognised several barriers to the penetration of HACCP, especially in SMEs: lack of knowledge, expertise and adequate resources. Similarly, a Spanish study regarding perceived barriers to the implementation of HACCP, focused on attitudes of company quality managers and external consultants (Vela and Fernandez, 2003). Whereas important results were generated in these studies, perhaps too little emphasis was placed on the attitudes of the company labourers. It is largely accepted that risk management strategies work only if they are internalised by all

Table 3.41 ISO 22000 analysis worksheet for the determination of prerequisite programmes for Provolone/Romano/Parmesan.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Milk receipt/temper milk	Yes	Yes	No	No	No
Addition of starter	Yes	Yes	No	Yes	Yes
Rennet	Yes	Yes	No	Yes	Yes
Curd formation					
Draining/dipping of curd	Yes	Yes	No	Yes	Yes
Ripening	Yes	Yes	No	Yes	Yes
Pressing	Yes	Yes	No	No	No
Milling	Yes	Yes	No	No	No
Salting	Yes	Yes	No	No	No
Ripening	Yes	Yes	No	Yes	Yes
Storage	Yes	Yes	No	No	No

Table 3.42 ISO 22000 analysis worksheet for the determination of prerequisite programmes for Cheddar cheese.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Milk receipt	Yes	Yes	No	No	No
Pasteurisation	Yes	Yes	No	No	No
Ripening	Yes	Yes	No	No	No
Rennet	Yes	Yes	No	Yes	Yes
Cooking	Yes	Yes	No	Yes	Yes
Draining	Yes	Yes	No	Yes	Yes
Milling	Yes	Yes	No	No	No
Salting	Yes	Yes	No	No	No
Pressing	Yes	Yes	No	No	No
Storage	Yes	Yes	No	No	No
Distribution	Yes	Yes	No	No	No

company employees, and that a successful implementation of HACCP demands commitment by the whole personnel (Mortimore, 2001; Panisello and Quantick, 2001).

The prevalence of biofilms in dairy processing is an important reservoir of both spoilage and pathogenic microflora which can lead to spoilage of finished product and transmission of diseases. It is recommended that each and every plant should be evaluated for the prevalence of biofilms. An effective sanitation programme should then be devised based on *in vitro* studies that could be invariably repeated under *in situ* conditions in order to control the biofilms prevalent in dairy/food processing areas.

Biofilm status of different segments of pasteurisation lines of commercial plant (CP) and an experimental dairy plant (EDP) was evaluated by Sharma and Anand (2002). Biochemical differentiation of organisms in biofilms revealed the predominance of genus *Bacillus* (37 and 44%, respectively) in both the plants. The other microflora of CP included *Lactobacillus*, *Streptococcus*, *Lactococcus* and *Staphylococcus*, while microflora of EDP additionally had *Micrococcus* sp. The Gram-negative genera in the constitutive microflora of biofilms were mainly Shigella, *E. coli*, *Enterobacter aerogenes*, *Citrobacter*, *Flavobacterium* and *Proteus* in CP, while EDP additionally had *Klebsiella* sp. A sanitiser, iodophore, at a concentration of 10 ppm

Table 3.43 ISO 22000 analysis worksheet for the determination of prerequisite programmes for Gruyère/Emmental.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Milk receipt	Yes	Yes	No	No	No
Addition of starter	Yes	Yes	No	Yes	Yes
Rennet Curd formation	Yes	Yes	No	Yes	Yes
Cutting	Yes	Yes	No	No	No
Cooking	Yes	Yes	No	Yes	Yes
Dipping	Yes	Yes	No	Yes	Yes
Pressing	Yes	Yes	No	No	No
Salting	Yes	Yes	No	No	No
Cool/warm room treatment	Yes	Yes	No	No	No
Packaging of cheese blocks	Yes	Yes	No	Yes	Yes
Ripening	Yes	Yes	No	Yes	Yes

Table 3.44 ISO 22000 analysis worksheet for the determination of prerequisite programmes for Camembert cheese.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Milk receipt	Yes	Yes	No	No	No
Pasteurisation	Yes	Yes	No	No	No
Starter	Yes	Yes	No	Yes	Yes
Rennet Curd formation	Yes	Yes	No	Yes	Yes
Cutting	Yes	Yes	No	No	No
Cooking	Yes	Yes	No	Yes	Yes
Dipping	Yes	Yes	No	Yes	Yes
Dry-salting	Yes	Yes	No	No	No
Wrapping	Yes	Yes	No	Yes	Yes
Storage	Yes	Yes	No	No	No

with a contact time of 20 minutes was found to be most effective to control mixed species biofilms of CP under *in vitro* and *in situ* conditions. Therefore, evaluation of biofilm status and development of an effective sanitation plan should be part of the HACCP plan in conjunction with ISO 9000 specifications for the dairy processing industry.

Results of a marketing study associated with the implementation and maintenance of HACCP in a pasteurised milk plant are presented by Roberto *et al.* (2006). The GMP/SSOP prerequisites were evaluated in the plant. Two HACCP plans were proposed: the first plan was developed under the actual operating conditions, without previous compliance of GMP/SSOP prerequisites, and a second plan in compliance with GMP/SSOP. The cost estimation for implementation and maintenance of HACCP, with or without previous adoption of the prerequisite programmes, was performed and a comparative analysis of the estimated values was carried out.

The results suggested that a previous compliance of GMP/SSOP prerequisites is essential for developing an effective HACCP plan with low number of CCPs, leading to lower costs and investments for implementation and maintenance of HACCP. For the HACCP plan with eight CCPs, the implementation cost for the first year amounted to R$177,538. With the compliance of the prerequisite programmes (GMP/SSOP), it was possible to reduce these costs approximately by 24.2%. This fact emphasised the importance of a solid prerequisite programme to improve economic viability for HACCP implementation.

Packaging materials are often considered as CCP in HACCP systems of food companies. Methods for the determination of the microbial contamination rate of plastic cups, especially for dairy products, must reliably detect single moulds, yeasts or coliforms. Even if packaging is sterilised before dispensing, a low contamination rate in the delivered packaging materials is demanded by the food producer.

Common sterilisation techniques such as UV sterilisation can be reduced in effectiveness by dust. The application of sterilisation by heat or steam is limited by possible thermal deformation of plastic cups. Thus, a sterilisation method for plastic cups needs to be found that ensures excellent hygienic conditions and does not influence the mechanical characteristics of the cups. Electron beam irradiation is a simple and easily applicable method to decontaminate plastics without changing the mechanical characteristics. The method has been used for the sterilisation of medical disposable products such as Petri dishes or catheters for many years. The principle is that electrons are accelerated in an electric field and then focused into a beam. The accelerated electrons interact with the product and deposit their energy in the form of ionising radiation, thus irreversibly damaging large molecules such as DNA and micro-organisms, resulting in sterile products.

Tacker *et al.* (2002) compared a specially adapted coating method, impedance method, direct inoculation and membrane filter technique to determine contamination with yeasts, moulds, coliforms and total bacterial counts using the appropriate agar in each case. The coating method is recommended for determining yeasts, moulds and coliforms as it allows the localisation of the micro-organisms as well as the determination of single micro-organisms. For total bacterial count, a direct inoculation technique is proposed. The employing of simple measures in the production and during transport of packaging materials, such as dust prevention or tight sealing in polyethylene bags, heavily reduces microbial contamination rates of packaging material. To reduce

Table 3.45 Representative prerequisite programmes.

1. Water supply (PP1)	
Hazards	*Biological* Pathogen recontamination (not meeting criteria for potable water) *Chemical* Cross-contamination – non-food chemicals (chlorine, water treatment chemicals, agricultural chemicals) *Physical* Hazardous extraneous material
HACCP prerequisite criteria	• Periodical microbiological and chemical control • Chlorination • Filtering • Distinct separation of potable and non-potable water circulation systems
Corrective actions	• Cease the use of problematic source, find alternative • Destroy contaminated products • Chlorination
Responsibility	• HACCP coordinator • Technician
2. Premises/equipment (PP2)	
Hazards	*Biological* Pathogen recontamination/pathogen growth Pathogen survival due to inadequate maintenance and/or calibration *Chemical* Cross-contamination – non-food chemicals (chemicals, agricultural chemicals) *Physical* Hazardous extraneous material
HACCP prerequisite criteria	• Building structure, adequate materials used (permit cleaning, minimise risk of contamination, provide adequate working space) • Sanitary facilities (lavatories, washbasins) • Ventilation: environmental air quality • Air: intake air source well located; filtered (specifications) • Drains: well located; adequate size • Lighting • Provide temperature-controlled handling • Written, implemented and effective preventative maintenance programme (calibration, servicing, replacement) ▪ designated responsibilities ▪ complete ▪ specifies procedures and frequency ▪ verified and updated
Corrective actions	• Change, repair so as to adhere to legal requirements • Head of each department
Responsibility	• Technician/engineer
3. Transport and storage (PP3)	
Hazards	*Biological* Pathogen contamination and/or recontamination from damaged packaging Microbial growth due to temperature abuse or to excess humidity *Chemical* Cross-contamination – non-food chemicals *Physical* Hazardous extraneous material from damaged packaging
HACCP prerequisite criteria	• Food carrier suitability to transport food • Product separation during transport and storage • Temperature control for ingredients and finished product (monitored and recorded) • Storage and handling requirements for incoming materials • Receiving and storage requirements for non-food chemicals • Finished product storage/shelf life observation/FIFO • Distribution: truck suitability/temperature requirements/FIFO

(*Continues*)

Table 3.45 (Continued)

Corrective actions	• Reject all expired, contaminated and affected products • Restore desirable storage conditions
Responsible	• Storage manager • Production manager • HACCP coordinator
4. Sanitation and pest control (PP4)	
Hazards	*Biological* Pathogen contamination and/or recontamination from unclean areas/equipment Pathogen contamination from rodents, insects etc. *Chemical* Cross-contamination – non-food chemicals Cross-contamination – ingredients (allergy sensitivities) Cross-contamination – pest control products *Physical* Hazardous extraneous material from unclean areas/equipment
HACCP prerequisite criteria	• Written, implemented and effective sanitation and pest control programmes ▪ designated responsibilities ▪ complete ▪ specifies procedures and frequency ▪ verified and updated • Use of effective cleaners and sanitisers, periodical verification (swab tests etc.) • Quick removal of food waste • Pest control: incoming materials receiving; incoming materials storage; exposed processing areas
Corrective actions	• Repeat cleaning procedure • Repeat rinsing • Change detergents and cleaning agents and review sanitation programme • Hold and reject all contaminated products
Responsible	• Sanitation manager • HACCP coordinator
5. Personnel conduct and hygiene (PP5)	
Hazards	*Biological* Pathogen recontamination from employee handling Pathogen recontamination from incorrect practices Pathogen recontamination from damaged containers *Chemical* Cross-contamination – non-food chemicals (incorrect practices) Allergenic residues due to incorrect practices *Physical* Hazardous extraneous material
HACCP prerequisite criteria	• Good manufacturing and hygiene practices • Maintain high degree of personal cleanliness • Wear clean, protective clothing • Not a carrier of contagious diseases • Adhere to working instructions and standard operating procedures • Written, implemented and effective training programme • Technical training ▪ HACCP and monitoring ▪ prerequisite programmes and monitoring ▪ specific duties
Corrective actions	• Reprimand for not complying with the rules • Keep off duty • Repeat training
Responsibility	• Production manager

Table 3.45 (Continued)

6. Recall programme (PP6)	
Hazards	*Biological* Pathogen contamination Microbial toxins *Chemical* Cross-contamination – non-food chemicals Antibiotics Allergenic residues *Physical* Hazardous extraneous material
HACCP prerequisite criteria	• Written, implemented and effective recall programme ▪ designated responsibilities ▪ specifies methods and controls ▪ effectiveness procedure • Documentation for product code system • Production records • Distribution records • Complaint file • Recall procedure trial
Corrective actions	• Review and test recall programme
Responsible	• HACCP coordinator
7. Company's receiving programme/supplier evaluation and approval (PP7)	
Hazards	*Biological* Pathogens Microbial toxins due to temperature abuse *Chemical* Cross-contamination – non-food chemicals Antibiotics Pesticides Allergenic residues *Physical* Hazardous extraneous material (metal, glass, wood)
HACCP prerequisite criteria	• List all incoming material • Define specifications for incoming material (e.g. proper use of sanitisers, proper control of antibiotics etc.) • Define their specifications (B, C, P, acceptable food grade) • Define receiving requirements, verify product is acceptable type, examine for damaged packages • Design a monitoring programme for receiving, check specifications • Evaluate suppliers (questionnaires, on site, quality certificates etc.) • Packaging materials, acceptable material specifications, handling (damage)
Corrective actions	• Reject and formally complain to the supplier • Find and recall all products containing unacceptable raw materials
Responsible	• Storage manager • HACCP coordinator

B, biological; C, chemical; P, physical.

contamination rates further, electron beam irradiation was applied: plastic cups sealed in polyethylene bags were treated with 4–5 kGy, a dose that already leads to sterile polystyrene and polypropylene cups without influencing mechanical characteristics of the packaging material.

3.14 YOGHURT

Acoustical measurements have advantages over other measurements in food monitoring because they make it possible to measure with non-contact and non-destructive surfaces and contribute to the

hygienisation of the food manufacturing industry. Ogasawara *et al.* (2006) tried to monitor lactic fermentation of yoghurt by a probing sensor using a pair of acoustic transducers. Temperature of the solution changed because of the reaction heat of fermentation. Consequently, the sound velocity propagated through the solution also changed depending on the temperature. At the same time, the solution changed its phase from liquid to gel. The transducer's usage in the solution indicates the change of the temperature as the change of the phase difference between two transducers. The acoustic method has advantages of nondestructive measurement that reduces contamination of food products by measuring instruments.

The sensor was inserted into milk with a lactic acid bacterial stain of 19°C and monitored phase retardation of propagated acoustic wave and its temperature with thermocouples in the milk. The monitoring result of fermentation from milk to Caspian Sea yoghurt by the acoustic transducers with the frequency of 3.7 MHz started to show gradient changes in temperature caused by reaction heat of fermentation but stopped the gradient change at the end although the temperature still changed. The gradient change stopped its change because of phase change from liquid to gel. The present method measured indirectly by setting transducers outside of the measuring object. This noncontact sensing method will have the great advantage of reducing the risk of food contamination from measuring instruments because the measurement probes are set out of fermentation reactor or food containers. The flow diagram for yoghurt is given in Fig. 3.12.

3.15 CONDENSED MILK

Condensed or concentrated milk is the liquid food obtained by partial removal of water from milk. Bulk-condensed milk is usually made by evaporation of manufacturing-grade milk without addition of sugar or any other preservative material. The primary use of the product is as a source of milk solids in confectionery, bakery and other manufactured foods. Heat treatments vary, but begin with pasteurisation.

After milking, the raw milk is chilled to below 48°C and kept at this temperature during its transportation to the dairy plant. At the plant, the receiver grades each milk load for odour, temperature, and foreign matter and antibiotics. After receipt, the milk is mechanically filtered and stored in silo tanks. For the manufacture of bulk skim condensed milk, the milk is preheated to 50–55°C and skimmed (0.5% fat) in a separator.

Milk is usually separated at temperatures between 38 and 62°C to facilitate separation and minimise damage to fat globules. Cream separated at temperatures below 45°C, however, contains active milk-derived lipases (Alan and Jane, 1994) that can initiate the development of rancidity during the short interval between separation and pasteurisation.

The skim milk is pasteurised at 72°C for at least 15 seconds for low heat and 93°C/3 minutes for high-heat condensed milk followed by cooling at 32°C regarding high-temperature short time (HTST) pasteurisation and concentrated by evaporation to the desired solids level. The condensed skim is then cooled to <5°C and stored in a silo, ready for dispatch. For the manufacture of bulk whole condensed milk, the process is identical except the separation step is eliminated (Ali and Fisher, 2002).

Concentration after heat treatment takes place under vacuum in multiple-effect evaporators. The degree of concentration depends on the product end use. The product leaving the evaporator is not sterile and further opportunities for contamination occur during post-evaporation handling. A high standard of hygiene together with rapid and efficient cooling is seen as an integral part of processing. After evaporation, the product is normally cooled to 20–25°C. The CCPs at the evaporation step are the examination of plant records for chemical, physical, bacteriological and temperature standards. The bulk-condensed whole and skim milk HACCP control chart is given in Table 3.46.

3.16 QUALITY CONTROL METHODOLOGY (QCM) FOR DETECTION OF MILK AND DAIRY PRODUCTS' AUTHENTICITY

The two most preferred methods for detecting mixtures of milk from different species in raw and further processed milk products are immunology (sandwich ELISA) and electrophoresis (PAGE, isoelectric focusing [IEF] and radial immunodiffusion). Hewedy and Smith (1989) found fast protein liquid chromatography (FPLC) the best method for detecting soy 'milk' in pasteurised bovine milk. Electrical conductivity and GLC (graphite-like carbon) can be used for the detection and estimation of cow's milk admixtures in buffalo's milk (El-Shabrawy and Hagag, 1980).

In products like cheese, the adulteration of milk fat with pure and partially hydrogenated soybean oils and other similar vegetable oils, such as cottonseed oil and corn oil, can be detected by GLC analysis of potassium salts of fatty acids, obtained after saponification of the fat (Luf *et al.*, 1987a,b).

A method for detecting and quantifying bovine, ovine and caprine milk mixtures in milk and cheeses

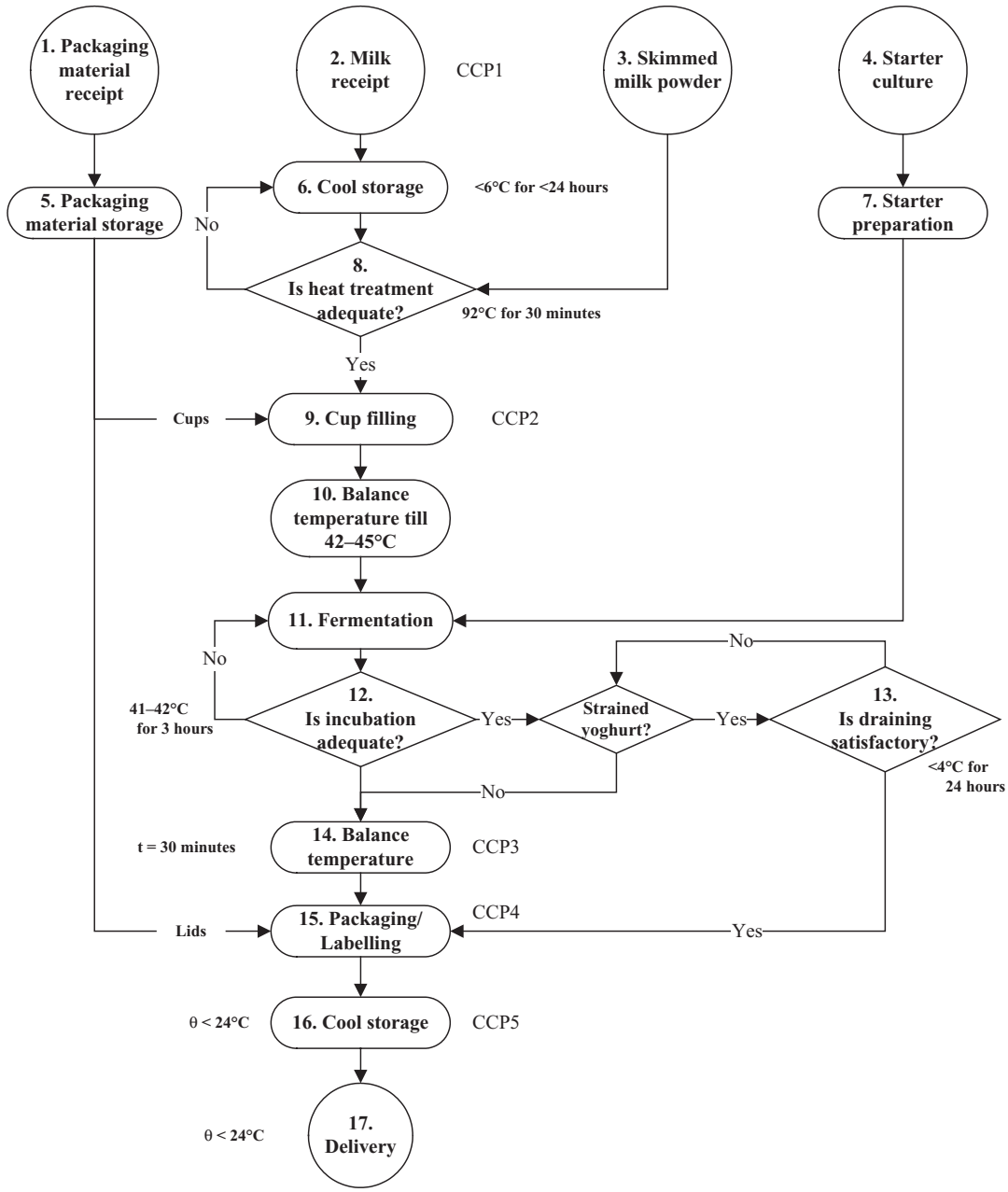

Fig. 3.12 Yoghurt flow diagram.

by means of reversed phase high-performance liquid chromatography (RP-HPLC) of β-lactoglobulins is described by Ferreira and Cacote (2003).

The implementation of multivariate methods to milk and dairy products revealed the emergence of several important parameters, such as mineral content, volatile analysis and sensory analysis, for the proper classification of dairy products, either in terms of geographic origin or variety. The most promising and effective multivariate analysis leading to the accurate separation of samples based on their attributes proved to be the principal component analysis, cluster analysis and canonical analysis (Arvanitoyannis and Tzouros, 2005).

Table 3.46 Bulk-condensed whole and skim milk HACCP control chart.

Processing step	Hazard	CCP	Critical limit	Monitoring	Records	Responsibility	Corrective action	Verification
Raw milk receiving	M, C	Temperature β-lactam	<5°C Absence	Every tanker	Receiving log	Receiving operator	Reject	Thermometer Drug test
Raw milk storage	M	Temperature, time	<5°C <72 hours	Continuous	Recording chart	Production supervisors	Hold product, investigate cause and adjust	Recording versus indicating thermometer
Pasteurisation	M	Temperature, time	>83°C >25 seconds	Continuous	Recording chart	Production supervisors	Flow divert recirculate and heat	Recording versus indicating thermometer

Adapted from Ali and Fischer (2002).
C, chemical; M, microbiological.

3.17 QCM FOR OTHER FERMENTED DAIRY PRODUCTS

Lben is a refreshing cultured product obtained by spontaneous fermentation of cow's milk. Occasionally, goat's milk alone or in combination with cow's milk is used; however, the same product is made in different Arab countries and it is known as lben or leben (in North African countries) and laban (in the Middle East; Benkerrouma and Tamime, 2004).

The traditional stages of manufacture of lben or other related products involve souring of milk at ambient temperature until coagulation occurs which may take up to 24–72 hours depending on the temperature during the summer and winter seasons, respectively. On gelation, the product is called rayeb, and may be consumed as such; however, by churning the fermentate, the product is separated into lben and raw butter called zebda beldia literally meaning 'butter of the county' (in other Middle Eastern countries, the same product is known as zibdeh baladieh, samna and in some instances, mutton fat dripping is also samen or samneh).

The churning is achieved by hanging the checoua filled with rayeb (ca. 10 L) to a wooden tripod or to a cottage roof and vigorously shaking it back and forth until fluidisation of the contents and coalescence of the fat globules (ca. 45–60 minutes). The end of churning is discerned by the sound of the butter lumps when shaking. Nowadays, the traditional churning is being gradually replaced by the use of electric mixers. These are metal containers, with different capacities, equipped with an agitator and a motor on the top.

Upon storage, lben sours and its acidity reaches high levels after 2–3 days. To avoid wastage culturally regarded as a sin, the product is excessively heated until separation of the curd and the whey occurs. The aqueous phase is decanted and the curd is called klila, which is then consumed as white fresh cheese. Raw butter is obtained after churning the fermented milk (rayeb).

A typical traditional procedure for jben making, known in other Arab countries as jibneh baida, which means 'white' cheese involves collection of raw milk (cow's, goat's or a blend of both) in an earthenware vessel and its fermentation spontaneously at ambient temperature until coagulation. At this stage, the curd (rayeb) is obtained in a similar manner as for lben, except that a larger volume of milk is needed and, hence, the period of filling the moulds extends over a period of 3–4 days. The curd is then transferred to a muslin cloth bag that is tied and hung to drain for an additional 2–3 days.

The cheese is then emptied from the cloth bag, cut into pieces (ca. 250 g), salted on the surface and conditioned for further draining.

Nowadays, rennet (addition of a freshly prepared infusion of dry calf stomach or by commercially made rennet [e.g. dry as a tablet or as liquid solution]) has been added to accelerate milk coagulation. These changes aim either at reducing the production time or at enhancing the safety and the keeping quality of the product.

Fermentation is achieved by the addition of yoghurt starter culture (ca. 1 g/100 mL) along with rennet. After the coagulation of the milk, the curd is dispensed into small-perforated plastic moulds where it is allowed to drain and later condition (Benkerrouma and Tamime, 2004).

3.18 UPDATED EU LEGISLATION

From 1 January 2006, new food hygiene legislation came into force throughout the EU. The legislation

affects all food businesses, including caterers, primary producers (such as farmers), manufacturers, distributors and retailers.

For the dairy industry, the legislation replaces the requirements of the Dairy Hygiene Directive 92/46/EEC. This directive contained many detailed prescriptive requirements, some of which were not consistent across the directives applying to other foods. The new legislation achieves consistency by applying to all foods, but with additional requirements applying to foods of animal origin such as dairy products. Although the result is a simplification of the requirements, unfortunately the task of achieving this has turned out to be more complicated than initially envisaged. The directives are being replaced by two main regulations together with subsidiary regulations and guidance documents. Underpinning the new hygiene package is Regulation 178/2002. This lays down the general principles and requirements of food law, and also establishes the European Food Safety Authority.

The main legislations in the new package are:

- Regulation 852/2004 on the hygiene of foodstuffs. This applies to all foods, and begins at primary production and continues through processing, distribution and retail. Finally, Regulation 852/2004 encourages national and community guides to the legislation, and it is expected that a number of these will be produced over the next year.
- Regulation 853/2004 laying down specific hygiene rules for food of animal origin.
- This gives additional requirements for foods of animal origin. There is a definition of such foods, the aim being to exclude composite products such as pizzas from the scope while applying the additional requirements to dairy and other foods of animal origin.
- Regulation 854/2004 laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption.
- Regulation 882/2004 on official controls performed to ensure the verification of compliance with feed and food law, animal health and welfare rules.
- There are also regulations giving transition measures, implementing measures and microbiological criteria. As well as this, the European Commission is issuing guidance on the interpretation of certain aspects of the legislation.
- The new legislation requires food business operators (except primary producers) to put in place, implement and maintain a permanent procedure, or procedures, based on the HACCP principles. The legislation is structured this way so that it can be applied flexibly in all food businesses regardless of their type or size.

Regulation 852/2004

The key requirements are:

1. Primary responsibility for food safety rests with the food business operator
2. Food safety throughout the food chain starts with primary production
3. Maintenance of the cold chain is important for food that cannot be stored safely at ambient temperatures, particularly frozen food
4. HACCP principles, together with the application of GHP, should reinforce food business operators' responsibility
5. Guides to good practice are to be encouraged
6. Microbiological criteria and temperature control requirements will be established based on a scientific risk assessment
7. Imported foods must be of the same hygiene standard or an equivalent standard as food produced in the community.

Primary producers will need to follow good practice and manage their operations as set out in Annex 1 of Regulation 852/2004.

Primary producers must ensure that hazards are acceptably controlled and respect other existing legislation but primary producers are not required to apply HACCP-based procedures.

Primary producers will have to be registered with competent authorities, although existing forms of registration may be used for this purpose.

Hazard analysis and critical control points

"Regulation 852/2004 requires food business operators to put in place, implement and maintain a permanent procedure or procedures based on the following HACCP principles:

- Identifying all hazards
- Identifying CCPs
- Establishing critical limits at CCPs
- Establishing and implementing effective monitoring procedures at CCPs
- Establishing corrective actions when monitoring indicates that a CCP is not under control
- Establishing procedures to verify that the above measures are working effectively
- Establishing documents and records commensurate with the nature and size of the food business."

General requirements for heat treatment

General requirements include the following (Regulation 852/2004):

1. Any heat-treatment process must (i) raise every part of the product treated to a given temperature for a given

period of time and (ii) prevent the product from becoming contaminated during the process.
2. Food business operators must check regularly the main relevant parameters (particularly temperature, pressure, sealing and microbiology), and the use of automatic devices.
3. The process used should conform to an internationally recognised standard (e.g. pasteurisation, UHT or sterilisation).

Specific requirements of Annex I of 852/2004
Specific requirements include the following:

- Primary products are to be protected against contamination.
- The cleanliness as far as possible of production animals is to be ensured.
- To keep clean any facilities used to store and handle feed.
- To ensure that staff handling foodstuffs are in good health and undergo training on health risks.
- To store and handle waste and hazardous substances so as to prevent contamination.
- To prevent the introduction and spread of contagious diseases transmissible to humans through food, including taking precautionary measures when introducing new animals and reporting suspected outbreaks of such diseases to the competent authority.
- To take account of the results of any relevant analyses carried out on samples taken from animals or other samples that have importance to human health.
- To use feed additives and veterinary medicinal products correctly, as required by relevant legislation.
- To keep and retain records relating to measures to control hazards in an appropriate manner and for an appropriate period. These records include:

  (i) The nature and the origin of feed fed to animals.
  (ii) Veterinary medicinal products or other treatments administered to the animals, dates of administration and withdrawal periods.
  (iii) The occurrence of diseases that may affect the safety of the products.
  (iv) The results of any analyses carried out on samples taken from animals or other samples taken for diagnostic purposes that have importance for human health.
  (v) Any relevant reports on checks carried out on animals or products of animal origin.

Food business operators are to take appropriate remedial action when informed of problems identified during official controls.

Specific requirements of Regulation 853/2004
There are specific additional dairy requirements in Regulation 853/2004 applying to primary production. In the main, these are similar or more flexible than the requirements of the Directive 92/46/EEC, but the following small differences are worth noting:

- Raw milk from any animal showing individually a positive reaction for tuberculosis or brucellosis must not be used for human consumption.
- The inspection requirements for milk from each animal have been modified to permit automatic milking. The new wording requires that milk from each animal be checked for organoleptic or physicochemical abnormalities by the milker or by a method achieving similar results and that milk presenting such abnormalities is not used for human consumption.
- Milk from animals showing clinical signs of udder disease must not be used for human consumption otherwise than in accordance with the instructions of a veterinarian.
- Teat dips or sprays are to be used only after authorisation or registration.
- Food business operators must initiate procedures to ensure that raw milk is not placed on the market if it contains antibiotic residues above permitted limits.
- When raw milk fails to comply with the standards for antibiotic residues, plate count or somatic cell count, the food business operator must inform the competent authority and take measures to correct the situation.

Regulation 853/2004 does not include additional heat-treatment requirements for dairy products but the Commission's regulation laying down implementing measures (Regulation 2074/2005) has reintroduced definitions for pasteurisation and UHT as follows:

1. Pasteurisation is achieved by a treatment involving (i) a high temperature for a short time (at least 72°C for 15 seconds); (ii) a low temperature for a long time (at least 63°C for 30 minutes); or (iii) any other combination of time and temperature conditions to obtain an equivalent effect, such that the products show, where applicable, a negative reaction to an alkaline phosphatase test immediately after such treatment.
2. UHT treatment is achieved by a treatment (i) involving a continuous flow of heat at a high temperature for a short time (not less than 135°C in combination with a suitable holding time) such that there are no viable micro-organisms or spores capable of growing in the treated product when kept in an aseptic-closed container at

ambient temperature; and (ii) sufficient to ensure that the products remain microbiologically stable after incubating for 15 days at 30°C in closed containers, or for 7 days at 55°C in closed containers, or after any other method demonstrating that the appropriate heat treatment has been applied.

3.19 CONCLUSIONS

Raw milk is normally stored at 4°C or below, at which temperature only psychrotropic organisms will grow. Subsequent pasteurisation will eliminate almost all the psychrotropic organisms. However, they frequently produce lipases and proteases that are markedly more thermoresistant than the organisms themselves. These enzymes may continue to function in pasteurised and otherwise heat-treated milk or products derived from it, particularly in so-called UHT-sterilised milk (Christen *et al*., 1986; Dunkley and Stevenson, 1987; Mossel *et al*., 1995).

It is well established that milk can be a potential carrier of disease-producing organisms. Milk-borne epidemics have occurred in the past throughout the world. Unless proper precautions are taken, such outbreaks of milk-borne diseases can occur anywhere, any time, especially if raw milk is consumed. Diseases, which are known to be transmissible through milk, are listed below, together with the manner in which they may enter the milk: (i) infection of milk directly from the cow, (ii) infection from man to cow and then to milk, (iii) direct contamination of milk by human beings and (iv) indirect contamination of milk by human beings (De, 2000).

A total of 193 outbreaks and 6053 illnesses from 1990 to 2005 were linked to such dairy products as cheese, milk and ice cream. Milk was the vehicle in 67 outbreaks with 1788 illnesses, cheese was identified in 57 outbreaks with 1850 illnesses and ice cream was identified in 49 outbreaks with 1879 illnesses. Dairy products identified as unpasteurised were associated with 30% of the dairy-related outbreaks, including nearly 70% of milk outbreaks. In outbreaks associated with dairy items, *Salmonella* and *Campylobacter* were the most common hazards (CSPI, 2007).

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4
Meat and Meat Products

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4.1 INTRODUCTION

As a general rule, slaughterhouses and meat establishments must fulfil two requirements:

1. The protection of products from external contamination and to follow high-hygienic standards.
2. The facilitating of the slaughter and butchering of animals so as to economically and efficiently produce meat for the market (Havas, 1995).

The Hazard Analysis and Critical Control Point (HACCP) concept provides a systematic approach to improve the preparation and handling of meat and poultry products, so as to reduce significantly foodborne illness (Tompkin, 1980). *Salmonella* infection is spread among animals or poultry through the use of contaminated feed and the incidence tends to reach a peak where intensive stock raising is practised (Crossland, 1997). To eliminate the presence of *Salmonella* in meat and poultry, it is necessary to maintain strict hygiene regimes and implement the HACCP concept (Simonsen *et al.*, 1987). To monitor the effect of these measures, it is necessary to screen raw materials, end products and materials in process for the presence of the pathogen (Morris, 1985).

Campylobacter jejuni/*E. coli* are found in the intestine of farm and domestic animals, in the intestine of poultry and in farm wastes. A strong relationship has been identified between poultry and food poisoning due to *Campylobacter* and there is some evidence that illness can be caused by infection with a small number of *Campylobacter* (Shapton and Shapton, 1994).

The separation of cooked and raw material is an essential prerequisite for food safety and thus the arrival of incoming raw materials is a significant critical control point (CCP) for the prevention of foodborne infections. Hermetic packaging of raw materials and ingredients maintains the majority of their hygienic and physicochemical properties, some of which are important for the final quality of the packaged product (Mossel and Stuijk, 1992; Put *et al.*, 1980). The controls that should be carried out at the receiving of raw materials and ingredients in order to minimise or prevent hazards, which might reduce their quality and pose danger to public health, are (i) identification of the product, (ii) presence of health mark or labels, (iii) certifications for guarantees, (iv) meat freshness/freezing date, (v) inspection of the product with respect to the physical state, surface colour and cleanliness, presence of abnormalities and extraneous materials, contamination by water or pests, and integrity of any wrapping or packaging, (vi) internal temperature of meat in relation to its physical state, upon receipt, it is important that raw materials be free from evidence of previous temperature abuse, (vii) microbial load and pH and (viii) temperature and hygienic conditions of the transporting vehicle (Severini and Trevisani, 1996).

Cooking is an important CCP and must be well controlled both for quality and for product safety reasons. The applied cooking process depends mainly on the required shelf life of the product. To achieve the maximum shelf-life extension for a product, it is particularly important to control the uniformity of heat distribution and the reproducibility of heating conditions. The critical limits that should be established for cooking and serving as safety boundaries are (i) the minimum internal temperature of the product, (ii) the composition and thickness of the product, (iii) time and rate of heating and cooling and (iv) oven temperature and humidity (NACMCF, 1992).

Cooling must also be strictly controlled, since germination and outgrowth of surviving spores (especially of *C. perfringens*) should be prevented (Hatheway *et al.*,

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1980). The final temperature and the rate of cooling determine the effectiveness of this process (Tavris *et al.*, 1985). It is important that manual handling is minimised and that the conveyor belts and the slicing machines are cleaned and disinfected frequently (ICMSF, 1988).

Canned, cured, shelf-stable meats have one of the most enviable safety records of most food products in relation to outbreaks of botulism. The principal microbiological hazard for pasteurised in-pack chilled meat products is foodborne botulism (Peck and Stringer, 2005). Canned, cured meats are considered in most markets to be standard commodity items with little premium attraction and they are consumed by most sectors of the community. Products include canned whole meats such as ham and meat emulsions including luncheon meat. Pork luncheon meat is replaced by beef luncheon meat in Jewish and Islamic communities. The products are sold under ambient storage conditions and have extensive shelf lives allocated to them. They are predominantly consumed without any further processing by the consumer and it is common for canned ham to be used as sandwich filling (Bell and Kyriakides, 2000a).

Products in this category, whether whole meat or emulsion based, are made under similar conditions and common to all is the absence of a process, e.g. a 'botulinum cook', which, in isolation, could prevent any hazard relating to *Clostridium botulinum*. The safety of these products is controlled by a combination of processing conditions and preservation factors which together reduce the number of spores and prevent the growth of *C.botulinum* during product shelf life.

Animals used for food, including cattle, pigs, sheep, and the young of these animals, all carry *Escherichia coli* as commensal flora, often different from the 'normal' strains in humans. They may also be infected by specific strains, again often different from those infecting humans. Strains pathogenic to humans carried in the 'normal' gut flora of food animals clearly pose a potential risk of infection to humans via a number of routes: (i) faecal–oral route from animals to humans during rearing processes, (ii) faecal contamination of food crops when untreated or poorly treated manure is used for fertiliser, (iii) faecal contamination of carcasses via poor hygienic practices during slaughter and evisceration processes and (iv) consumption of faecally contaminated raw milk, *E. coli* mastitic milk or products made from such milk.

South Australia experienced a large outbreak of *E. coli* food poisoning between December 1994 and February 1995 (Cameron *et al.*, 1995b). A total of 23 cases of haemolytic–uraemic syndrome (HUS) were reported among children less than 16 years of age, primarily in the Adelaide region (Cameron *et al.*, 1995a). Examples of food-associated outbreaks of illness caused by micro-organisms are given in Table 4.1 and the general characteristics of cattle, pork and goat meat are summarised in Table 4.2.

4.2 NEW COMMUNITY LEGAL BASIS

The evolution of the European Community legislation on food hygiene and safety will affect the situation in the meat industry from the stage of primary production to the final product on the retail market. The recent Community legislation was developed as a consequence of the adoption of the White Paper on Food Safety. The White Paper sets out over 80 separate actions that are envisaged over the period ahead and intends to close identified loopholes in current legislation (EC, 2000). On 23 July 2007, the member states of the European Union (EU) launched an Intergovernmental Conference (IGC) to draw up a new Reform White Paper for an EU of 27 member states (http://www.fco.gov.uk/Files/kfile/CM7174_Reform_Treaty.pdf). Regulation (EC) No. 178/2002, laying down the general principles and requirements of food law, establishing the European Food Safety Authority and defining procedures in matters of food safety, was considered as the foundation of the new legislation Regulation (EC) No. 178/2002.

The European Committee adopted a uniform legal policy applicable to the entire food chain from 'farm to fork' in order to protect public health and maintain high food safety standards. As a result, the European Parliament and the Council issued four Regulations that merged, harmonised and simplified the EU hygiene legislation that had previously been scattered over 17 separate Directives, composing the new food hygiene package. In general, this package includes rules and procedures related to the responsibilities of all food business operators for the hygienic production and safe disposal of food products as well as the responsibilities of the competent authorities in the control of foodstuffs for the implementation of the structural, operational and hygiene requirements. The four Regulations that entered into force on 1 January 2006 are:

- Regulation (EC) No. 852/2004 on the hygiene of foodstuffs.
- Regulation (EC) No. 853/2004 laying down specific hygiene rules for food of animal origin.
- Regulation (EC) No. 854/2004 laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption.

Table 4.1 Examples of food-associated outbreaks of illness caused by micro-organisms.

Food	Country	Micro-organism	Incidence	Reference
Raw pork	UK	*Clostridium botulinum*	14	Dodds (1993)
Vacuum-packed bacon	UK	*Clostridium botulinum*	73	Dodds (1993)
Raw meats	North America	*Clostridium botulinum*	1	Dodds (1993)
Raw meats	Europe	*Clostridium botulinum*	36	Dodds (1993)
Manufactured frozen meat pie	USA	*Clostridium botulinum*	1	Bell and Kyriakides (2000)
Raw sausage	UK	*Salmonella*	988	Bell and Kyriakides (2002)
Raw meat	UK	*Salmonella*	830	Bell and Kyriakides (2002)
Offal	UK	*Salmonella*	458	Bell and Kyriakides (2002)
Raw meat	Sweden	*Salmonella*	8845	Lundbeck *et al.* (1955)
Corned beef	Scotland	*Salmonella*	507	Walker (1965)
Salami	Australia	*Salmonella*	279	Taplin (1982)
Pate	France	*Salmonella*	506	Bouvet *et al.* (1986)
Ham	England and Wales	*Salmonella*	274	Bell and Kyriakides (2002)
Salami sticks	UK	*Salmonella*	101	Cowden *et al.* (1989)
Cooked meat	UK	*Salmonella*	545	Sockett *et al.* (1993)
Salami	Italy	*Salmonella*	83	Pontello *et al.* (1998)
Raw beef	Malaysia	*Listeria monocytogenes*	6	Arumugaswamy *et al.* (1994)
Fresh ground beef, fresh pork and sausages	Italy	*Listeria monocytogenes*	65	Comi *et al.* (1992)
Raw meat	Denmark	*Listeria monocytogenes*	106	Norrung *et al.* (1999)
Ground beef and steak	USA	*Listeria monocytogenes*	6	Amoril and Bhunia (1999)
Ground pork	USA	*Listeria monocytogenes*	171	Kanuganti *et al.* (2002)
Ready-to-eat meat	UK	*Listeria monocytogenes*	61	Elson *et al.* (2004)
Sliced meat	UK	*Listeria monocytogenes*	22	Elson *et al.* (2004)
Luncheon meats	USA	*Listeria monocytogenes*	82	Gombas *et al.* (2003)
Preserved meat products – not heat treated	Denmark	*Listeria monocytogenes*	77	Norrung *et al.* (1999)
Pork tongue in aspic	France	*Listeria monocytogenes*	279 (63 deaths)	Goulet *et al.* (1993)
Hot dogs and delicatessen meats	USA	*Listeria monocytogenes*	100 (21 deaths)	Bell and Kyriakides (2005)
Pork tongue in jelly	France	*Listeria monocytogenes*	26 (7 deaths)	Bell and Kyriakides (2005)
Ham and corned beef	New Zealand	*Listeria monocytogenes*	31	Sim *et al.* (2002)
Hamburger patties in sandwiches	Oregon and Michigan	*Escherichia coli*	47	Riley *et al.* (1983)
Undercooked beef patties	Canada	*Escherichia coli*	73 (17 deaths)	Chapman (1995)
Hamburgers	USA	*Escherichia coli*	732 (4 deaths)	Bell and Kyriakides (1998)
Uncooked, semi-dry fermented sausage (mettwurst)	South Australia	*Escherichia coli*	23 (1 death)	Cameron *et al.* (1995a)
Meat products	Scotland	*Escherichia coli*	490 (20 deaths)	Pennington (1997)
Minced mixed beef and pork	Netherlands	*Escherichia coli*	2	Heuvelink *et al.* (1996)

Table 4.2 General characteristics of cattle, pork and goats meat.

Products	Half-parts, quadric-parts cattle, pork half-parts, goats half-parts, offal, tongues, head meat
General characteristics	Fresh meat kept in cool chambers
Packing	Plastic packing of pork and cattle livers and offal from lambs/heads
Usage	Promotion in the retail sector, further treatment for the preparation of various meat-based products
Shelf life	7 days at 0–2°C
Storage and transport instruction	Stored in controlled conservation conditions (temperature 0–2°C, humidity 85–90%)
	Transport in refrigerated trucks
General specification	Products complied with the EEC directives 93/43, PD410/1994(91/497/EEC, 91/498/EEC, 92/120/EEC), 1760/2000, 72/461/EEC and the Code of Foods and Beverages

- Regulation (EC) No. 882/2004 on official controls performed to ensure the verification of compliance with feed and food law, animal health and animal welfare rules.

Regulation (EC) No. 852/2004 applies to all stages of production, processing and distribution of food and to exports and lays down general rules for food business operators on the hygiene of foodstuffs. This regulation takes into account the fact that primary responsibility for food safety rests within the food business operator. The operator should implement procedures based on the HACCP principles, apply good hygiene practice (GHP), apply hygienic measures to maintain the cold chain, establish microbiological criteria and temperature control requirements based on a scientific risk assessment and carry out laboratory checks following a proper sampling plan.

4.2.1 General hygienic provisions for primary production

Part A of Annex I of Regulation (EC) No. 854/2004 refers to the general hygienic provisions for primary production. This Regulation lays down specific rules for the organisation of official controls on products of animal origin. The implementation of measures relating to animal health and welfare and especially for the prevention of the introduction and spread of contagious diseases transmissible to humans through food is an essential consideration for the safe production of meat. Control of sources of contamination and the application of hygienic rules in terms of facilities, herd management and transport of animals influence the safety of meat for human consumption. In addition, herd owners should keep records of the nature and origin of animal feed used, veterinary medicinal products or other treatments administered to the animals, the occurrence of diseases that may affect the safety of products of animal origin and the results of any analyses carried out on samples taken from animals for diagnostic purposes especially those with public health significance. This information should be available to the competent authorities when animals enter the slaughterhouse.

A wide variety of veterinary drugs are used in animal production. Table 4.3 lists the major classes and gives the use of veterinary drugs. Essentially, veterinary drugs are most likely to occur in animal-derived food products, although drug residue in animal waste is a growing concern (Lehotay and Mastovska, 2005). Among the actual measures required for ensuring hygiene in primary production are (i) cleaning of animal udders before and after milking, (ii) cleanliness in the farmyard, (iii) combating pests and preventing wild birds and pets from gaining access to production areas, (iv) prevention of contamination when handling

Table 4.3 Classification of veterinary drugs.

Class	Uses
Antibacterial drugs	Treatment and prophylaxis of diseases caused by bacteria
Antihelminthic drugs	Treatment and prophylaxis of parasitic infestations
Anticoccidial and other antiprotozoal drugs	Treatment of protozoal infections
Antimicrobial growth promoters	At subtherapeutic dosages for improved feed for an extended period of time
Anabolic hormonal-type growth promoters	Use of different types of steroids. Not permitted in the EU
Antifungal drugs	Treatment and prophylaxis of diseases caused by fungi
Corticosteroids	Prohibited for growth-promoting purposes in many countries (including the USA and EU)
Thyreostatic drugs	Prohibited in animal breeding worldwide

waste or dangerous substances and disposing of dead animals and (v) protective measures to prevent the introduction and spread of contagious diseases and epidemic animal diseases (http://eur-lex.europa.eu/LexUriServ/site/en/oj/2003/ce180/ce18020030731en02780280.pdf).

4.2.2 General hygienic provisions for food establishments

Food premises, including slaughterhouses, should comply with the general and special requirements defined in Annex II of Regulation (EC) No. 854/2004 laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption. The layout, design, construction and size of food premises should allow for good hygienic practices, including protection against contamination between and during operations, permit adequate maintenance, cleaning and/or disinfection. They should also provide suitable temperature-controlled handling and storage conditions of sufficient capacity for maintaining foodstuffs at appropriate temperatures, have suitable and sufficient means of lighting and ventilation and have adequate drainage facilities suitably designed and constructed. In particular, the floor and wall surfaces, the ceilings, the windows and doors should be maintained in a sound condition and be easy to clean and disinfect, when necessary. The use of impermeable, non-absorbent, washable and non-toxic materials is required as well as conditions to prevent food-handling areas from any sources of contamination. The same requirements are defined for surfaces, utensils, fittings and equipment with which food comes into contact. Adequate provision is to be made for the storage and disposal of waste in a hygienic and environmentally friendly way. Potable water must be used to ensure that foodstuffs are not contaminated by waterborne bacteria and non-potable water, if used, should circulate in a separate duly identified system to avoid both mixing with potable water and contact with food-handling areas.

Personal hygiene is a fundamental issue and no person suffering from, or carrying a disease likely to be transmitted through food, is to be permitted to handle food or enter any food-handling area. The most commonly recognised infections are those caused by the bacteria *Campylobacter*, *Salmonella* and *E. coli* O157:H7. It is estimated there are more than 9 million cases of gastroenteritis each year in England. Gastroenteritis describes symptoms affecting digestion, such as nausea, vomiting, diarrhoea and stomach pain. Food poisoning is the type of gastroenteritis caused by eating or drinking something contaminated with micro-organisms or germs, or by toxic substances produced by these germs. These illnesses are often accompanied by fever, muscle aches, shivering and feeling exhausted (http://www.bbc.co.uk/health/conditions/foodpoisoning1.shtml).

The food business operators should ensure that food handlers are supervised and instructed and/or trained in food hygiene matters and have received adequate training in the application of HACCP principles.

4.2.3 Registration and approval of food establishments

All food establishments fulfilling the above requirements are registered by the competent authority. Food business operators should only place products in the market originating from an approved establishment. The competent authority may grant approval to an establishment if it meets the relevant requirements of Regulations (EC) No. 852/2004 and (EC) No. 853/2004 and other relevant requirements of food law, following an on-site visit. An establishment receives a complete or conditional approval by the competent authority under the terms defined in Regulation (EC) No. 854/2004. Products of animal origin are also placed in the market if they have an identification mark applied in accordance with Regulation (EC) No. 854/2004, indicating that the product has been manufactured according to the provisional legal requirements. The mark should indicate the approval number of the establishment.

4.2.4 Application of a HACCP system

The implementation of a HACCP system in the slaughterhouse is an essential management tool, as animals accepted there originate from herds of different quality and *ante-mortem* and *post-mortem* veterinary inspection cannot completely eliminate or reduce effectively contamination hazards for the production of safe meat (Mortimore and Wallace, 1998). According to Annex II of Regulation (EC) No. 853/2004, food business operators operating slaughterhouses should ensure that they have put in place procedures based on the principles of a HACCP system.

The procedures guarantee that:

- each animal accepted onto the slaughterhouse premises is properly identified
- accompanied by the relevant information from the holding of origin and is healthy and in satisfactory state regarding welfare
- the animal does not come from a holding or area subject to a movement prohibition or restrictions for health purposes or public health

- rules on the use of veterinary medicinal products have been complied with
- no other condition which might adversely affect human or animal health is present.

This information should be provided no less than 24 hours before the arrival of animals at the slaughterhouse, except in special circumstances (e.g. animal subject to emergency slaughter).

Data collected should cover:

- the health status of the holding of origin and of the animals
- the veterinary medicinal products or other treatments administered to the animals
- the occurrence of diseases that may affect the safety of meat
- the results of any laboratory analysis to diagnose diseases and any other report submitted by the official veterinarian.

Food business operators should only accept animals onto the slaughterhouse premises following the evaluation of the relevant food chain information by the official veterinarian. Slaughter of the animal should take place only when the official veterinarian has given approval.

4.2.5 Slaughterhouse hygienic requirements

In accordance with Annex III of Regulation (EC) No. 853/2004, slaughterhouses should have adequate and hygienic waiting pens with a drainage system that does not compromise food safety, pens for sick or suspect animals with separate drainage, sited in such a way as to avoid contamination of other animals. The layout of the pens must facilitate *ante-mortem* inspections.

The slaughterhouse should have also a sufficient number of rooms, appropriate to the operations being carried out and a separate room for the emptying out and cleaning of stomachs and intestines. They should ensure separation in space or time of stunning and bleeding, evisceration and further dressing, handling of clean guts and tripe, preparation and cleaning of other offal, particularly the handling of skinned heads if it does not take place at the slaughter line, packaging of offal and dispatching of packaged meat. Installations must prevent contact between the meat and the floors, walls and fixtures. Slaughter lines (where operated) must be designed to allow constant progress of the slaughter process and to avoid cross-contamination between the different parts of the slaughter line:

There must be appropriate facilities for disinfecting tools and washing hands.

There must also be separate lockable facilities for the refrigerated storage of detained meat and of meat declared unfit for human consumption.

There should be predetermined procedures for the slaughter of sick and suspect animals.

4.2.6 Role of the official veterinarian

Ante-mortem inspection of every animal to be slaughtered should be carried out under suitable conditions. Hygiene rules must be respected during the slaughter operations and handling of the carcass. Slaughterhouse workers must follow the hygiene procedures for those parts of the carcass which must be removed, or need special handling in order to avoid contamination of the meat. *Post-mortem* inspection should be followed immediately by chilling in the slaughterhouse. The chilling temperature must also be maintained during transport. These temperature provisions may be unnecessary when the competent authority allows meat to leave the slaughterhouse immediately to be supplied as fresh meat at outlets within two hours travelling time of the slaughterhouse.

The *ante-mortem* and *post-mortem* inspections of meat, which have been implemented for over 30 years without major changes, are modified within the frame of the new hygienic package. These changes are intended to protect human health from food crises and new emerging diseases of animals and from hazards linked to methods of meat production especially those which have been introduced in the last 30 years.

Annex I of Regulation (EC) No. 854/2004 defines the auditing and inspection tasks for fresh meat which the official veterinarian should undertake. The initial task of inspection is the checking of the food chain information as listed above. The official veterinarian should verify that animals are not slaughtered unless the slaughterhouse operator has been provided with the relevant checked food chain information. The *ante-mortem* inspection should determine whether rules on animal welfare have been obeyed or whether there are signs of any condition likely to affect human or animal health, paying particular attention to the detection of zoonotic diseases and diseases on Office International Epizooties (OIE) listed diseases (e.g. foot-and-mouth diseases, vesicular stomatitis etc.).

When relevant food chain information is not available within 24 hours of an animal's arrival at the slaughterhouse, all meat from the animal should be declared unfit for human consumption. Based on the results of the *ante-mortem* inspection, the official veterinarian decides whether the normal slaughter process

will be followed, or if the animals are slaughtered or killed separately, or at the end of normal slaughtering, or under special conditions, taking, where necessary, precautions to avoid contamination of other carcasses and meat. The official veterinarian is also responsible for taking the necessary corrective measures, if the rules concerning the protection of animals at the time of slaughter or killing are not respected.

Post-mortem inspection must be carried out without delay with minimal handling of the carcass and offal or special technical facilities and there should be minimal special technical facilities for the detection of zoonotic diseases and diseases on list A and, where appropriate, list B of OIE. Additional examinations should take place, such as palpation and incision of parts of the carcass and offal and laboratory tests, whenever considered necessary, to reach a definitive diagnosis and to detect the presence of an animal disease or residues in excess of the levels laid down under Community legislation, or to show noncompliance with microbiological criteria or other factors that might require the meat to be declared unfit for human consumption. During the inspection, precautions should be taken to ensure that contamination of the meat by actions such as palpation, cutting or incision is kept to a minimum. In addition to the general requirements concerning audits of good hygiene practices, the official veterinarian verifies the handling and disposal of animal by-products including specified risk material, e.g. spinal cord and brain. Moreover, besides audits of HACCP-based principles, the official veterinarian checks that the operators' procedures guarantee that meat does not contain specified risk material and has been produced in accordance with Community legislation on Transmitted Spongiform Encephalopathies (TSEs). If necessary, samples may be taken for the monitoring and control of zoonoses and zoonotic agents, for the diagnosis of TSEs in accordance with Regulation (EC) No. 999/2001 of the European Parliament and of the Council, the detection of unauthorised substances within the framework of the National Residue Plans and the detection of OIE list A and list B diseases (Regulation (EC) No. 999/2001). Based on the *post-mortem* inspection, the official veterinarian determines the cases and the conditions under which the meat is to be declared fit or unfit for human consumption. Finally, the official veterinarian has to supervise the health marking and the use of the appropriate marks, only applied to animals having undergone *ante-mortem* and *post-mortem* inspection in accordance with this Regulation. In the same Annex, special requirements for *post-mortem* inspection procedures for carcasses and offal of bovine, porcine and ovine/caprine animals are included as well as actions for controlling specific hazards, such as zoonoses and TSEs, with the aim of protecting public health.

4.2.7 Recording of *ante-mortem* and *post-mortem* inspection results

The results of inspection activities are recorded, evaluated and communicated to the food business operator if the presence of any disease or condition that might affect public or animal health or compromise animal welfare is revealed. If the problem identified has arisen during primary production, the herd owner and the veterinarian responsible for the holding of origin are informed and if the presence of an infectious agent mentioned in OIE list A or list B is suspected, the competent authority must be notified so as to allow the necessary measures in accordance with the applicable Community legislation to be taken. The results of the inspections and tests are to be included in relevant databases.

4.2.8 Professional qualifications of inspectors

The inspection process, either *ante-mortem* or *post-mortem*, is a task of special responsibility requiring the continuous presence of an experienced veterinarian in the slaughterhouse. Regulation (EC) No. 854/2004 refers to the necessary background and professional qualifications of the official veterinarian. The veterinary should have knowledge of relevant aspects of good farming, manufacturing and hygiene practices; quality management; principles, and methods of HACCP, auditing and regulatory assessment of food safety management systems; aspects concerning TSEs; and zoonoses and foodborne diseases. Candidates may acquire the necessary knowledge as part of their basic veterinary training, or through specialist training, or professional experience acquired, after qualifying as veterinarians. Each official veterinarian should undergo practical training for a probation period before starting to work independently. Since the inspection procedure is complicated and time-consuming, the present regulation allows the competent authority to appoint official auxiliaries only if they have undergone sufficient special training, theoretical and practical, to assist the official veterinarian.

4.2.9 Official control of slaughterhouses

The official control of the slaughter establishments, the operational procedures and the level of hygiene practice in compliance with the relevant legislation are the responsibility of the competent authority of each member state according to Regulation (EC) No. 882/2004.

This regulation contains rules underpinning the integrated and horizontal approach necessary to implement a coherent control policy on feed and food safety, animal health and animal welfare. The requirements of the competent authority to organise the official control and the obligations to perform it are determined. Official controls are performed with impartiality, quality and in accordance with documented procedures. The staff performing official controls must receive appropriate training enabling them to undertake their duties competently and in a consistent manner.

4.3 GOOD MANUFACTURING PRACTICES

Good manufacturing practices (GMPs) are sometimes referred to as 'control points' and are defined as the correct processes and procedures to be followed in the preparation of food to prevent microbial, chemical and physical contamination of the finished product. In other words, GMPs define what has to be done to prevent contamination, when it has to be done and by whom. GMPs do not address specific hazards, and loss of control would not necessarily result in an acceptable health hazard to the consumer. Areas covered by the GMP programme include:

- personnel, including task and hygiene training, job description and organisational structure
- premises, including location and structure
- equipment, including design, maintenance and calibration
- services, including sanitary services, disposal of waste materials, the provision of electricity, water, refrigeration and steam
- raw materials, including live animals, packaging, food ingredients and chemicals
- product traceability
- documentation.

4.4 GENERAL HYGIENE PRACTICES

Within the GMP 'umbrella', cleaning and hygiene are given their own subsection referred to as GHP. This may be defined as those operations involved in providing a clean sanitary environment for the preparation, handling and storage of fresh meat. In other words, the GHPs define what has to be done in relation to cleaning and hygiene, when it has to be done and by whom. Areas covered by the GHP programme include:

- the cleaning of plant and equipment
- staff health in relation to food handling and staff cleanliness
- the cleanliness of the raw materials including live animals
- ensuring that all detergents, sanitisers and other non-food chemicals are properly packaged and labelled, comply with their specifications and are stored correctly.

4.5 STANDARD OPERATING PROCEDURES

The standard operating procedures (SOPs) are established or prescribed methods to be allowed routinely for the performance of designated operations or in designated situations. These may simply be referred to as 'procedures' as they include procedures for each step during routine slaughter, procedures telling how each GMP and GHP is to be carried out and procedures to be followed at each CCP. In other words exact procedures for carrying out specific tasks are detailed as SOPs.

4.6 APPLICATION OF HACCP IN BOVINE FATLING

Receipt of animals is the first CCP and sorting of animals is the second one. All animals need to be labelled once the veterinary tests are completed. Animals that might contain antibiotic residues or other chemical substances should be removed at this point before entering the butchering process.

Careful attention is needed during exsanguination as there is a danger of cross-contamination if the wrong techniques are used. Knives should be washed in cold water and then disinfected by heating at 85°C, under pressure, 7–13 Pa for at least 20 seconds. Hygiene rules which are required from the legislation should also be applied.

During processing the skin of the carcass is removed. At this stage, there is the danger of cross-contamination because pathogenic micro-organisms can be transferred from the animal's skin to the meat or the head. For this reason workers should apply hygienic rules and always sterilise tools before slaughtering the next animal. The process of skin removal must always be checked to ensure its effectiveness.

Following skinning, the animal is transferred to the clean area where the head is removed, front legs and chest are cut and the offal removed. Full removal of the intestines including faeces and undigested food should be carried out carefully to avoid any cross-contamination. The veterinarian should control this

Table 4.4 Results of HACCP implementation in bovine fatling.

Ingredients	CCP	Dangers	Description of dangers	Preventive measures
Muscular and fat tissue	Animal sorting Haemorrhage Head removal, legs, offal Cooling	*E. coli* Aerobic micro-organisms	Growth of pathogens due to lack of basic equipment	Improvement of hygienic quality Control at each handling

process. Only with the veterinarian's approval can the meat proceed to further processing.

The carcass is then cooled to 4°C before being cut into pieces of different sizes and packaged. Second packaging is then essential for the sale of fresh meat. Packaging materials should be approved and appropriate for the product to avoid the presence of chemical dangers. After packaging meat not for the fresh market should be frozen at −18°C (http://www.usda.gov).

Research carried out in the slaughterhouses of South Australia which were operating under HACCP found an aerobic microbial population was present as well as *E. coli* in samples taken from muscular tissue or fat tissue. HACCP was operational both in slaughterhouses and in freezing rooms. The growth of *E. coli* in bovine carcasses in small slaughterhouses was minimal compared to the growth observed in large slaughterhouses.

In bovine carcasses, the aerobic count in small slaughterhouses was similar to that of the big slaughterhouses (median log 1.72 and 1.81). *E. coli* on bovine carcasses was 4.7% in very small slaughterhouses and 28.4% in big slaughterhouses when swabs were taken over an area of 200 cm^2.

4.6.1 Corrective action

The hygiene in slaughterhouses should be improved in order to reduce further the number of microorganisms. Control of a simple time course should be maintained in every operation in order to record the seasonal effects (Sumner *et al.*, 2003).

The application of HACCP in bovine fatling is summarised in Table 4.4 and the flow diagram is given in Fig. 4.1. The evaluation templates of the present risks for the CCP's determination, the ISO 22000 analysis, the concentrative template of monitoring HAACP and the comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with prerequisite programmes (PRPs) for the bovine carcass are summarised in Tables 4.5–4.8, respectively.

4.7 APPLICATION OF HACCP IN SWINE FATLING

Processing stages during receipt of swine fatling, and their processing and distribution as meat products in slaughterhouses, are described in a flow diagram (Fig. 4.2). From this diagram, CCPs and critical limits were determined and corrective actions have been suggested. Table 4.9 shows the CCPs, critical limits as well as corrective actions required.

Animals are held in lairage, before being stunned using carbon dioxide and transferred into the 'wet' room, where exsanguination should be achieved immediately by severing the carotid arteries and jugular vein. Exsanguinated animals should be scalded for approximately 8 minutes using a linear 'scald tank' (61°C). Scalded carcasses are dehaired using a rotating drum with scrapers that flail the carcass surface, dislodging hair and skin debris.

Dehaired carcasses are secured to an overhead conveyor rail by insertion of a gambrel hook into the hind leg tendons. Carcasses are then passed through a singer operating at approximately 1200°C for 15 seconds. Singed carcasses are polished by passage through a series of horizontal and vertical flails in a process that lasts approximately 5 minutes (Pearce *et al.*, 2004).

Polished carcasses should be moved into a separate evisceration area. Carcasses are 'debunged' by cutting around the rectum with a knife, which had been immersed in water heated to 82°C before use. The detached rectum should be sealed with a plastic bag to prevent faecal contamination of carcasses during subsequent processing. The belly is opened and the diaphragm, heart, lungs, trachea, and the digestive tract removed. Carcasses are manually split along the midline, from the hind to the fore using a splitting saw, the heads removed, and the spinal cord excised. Carcasses are then trimmed, weighed and graded, before spray washing for approximately 10 seconds with cold potable water containing between 0.8 and 1.2 ppm chlorine (to remove bone dust and blood clots).

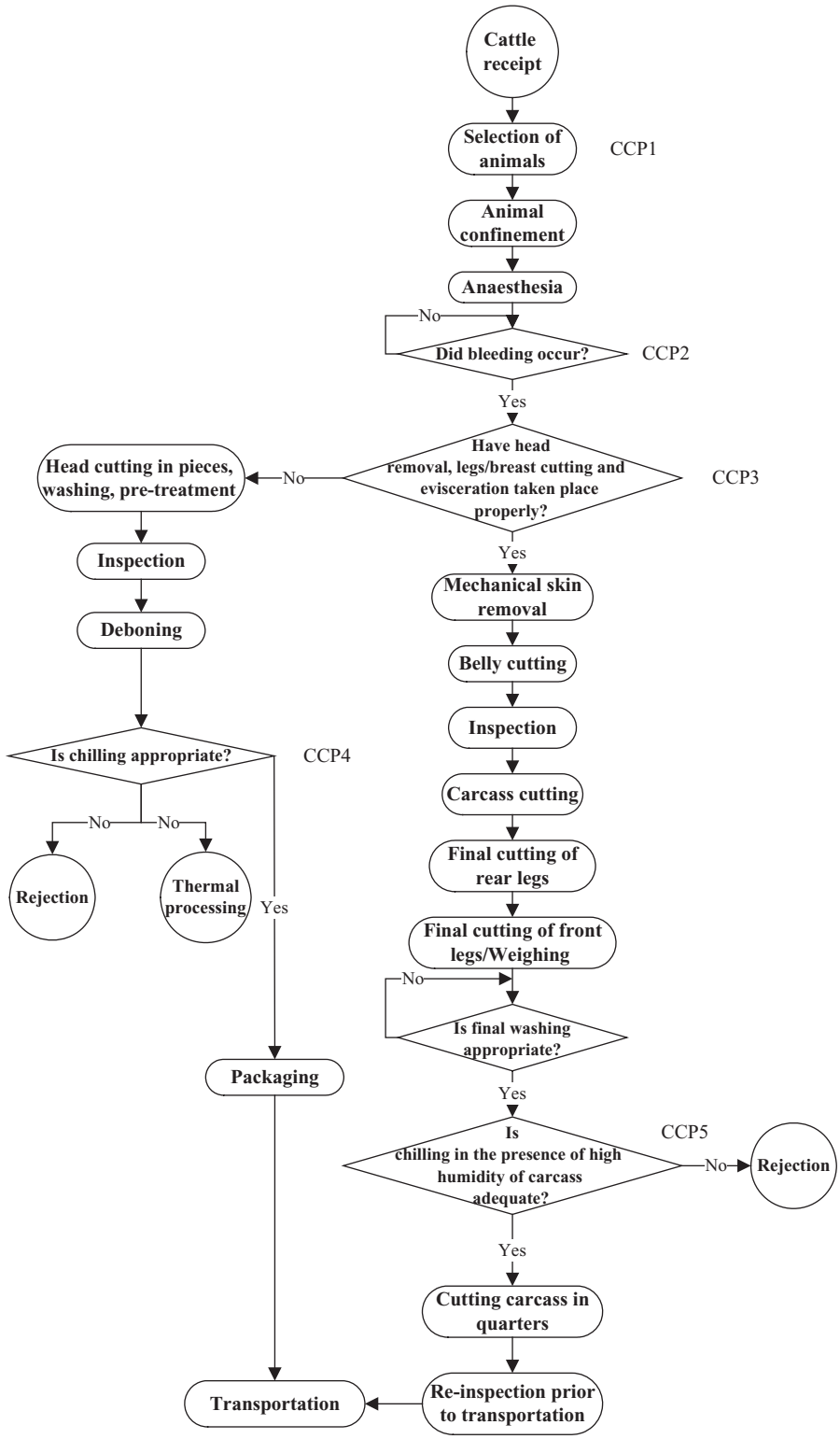

Fig. 4.1 Flow diagram of bovine carcass.

Table 4.5 Evaluation templates of the present risks for the critical control points (CCPs) determination in the bovine carcass.

A/A CCP	Process stage	Kind of risk	Description of possible risks	Q1	Preventive actions	Q2	Q3	Q4	CCP
1	Cattle receipt	Biological	Cross contamination caused by dirty animals	Yes	Washing	No	Yes	Yes	
	Veterinary inspection	Biological	Animals polluted with parasites	Yes	Visual control	No	Yes	Yes	
	(Veterinary responsibility)	Biological	Animals contaminated with parasites or pathogens non-visible in a macroscopic examination	Yes	Control of the animal health documents	No	Yes	No	
		Chemical	Animals loaded with antibiotics, medicines remnants, hormones, herbicides	Yes	Control of the animal health documents/periodical laboratory controls	No	Yes	No	
		Physical	Metallic objects found on the muscular tissue of the animals	Yes	Visual control	No	Yes	Yes	
2	Water licence	Biological	Microbial load of the carcass with micro-organisms from water	Yes	Water monthly microbiological control	No	Yes	No	
		Chemical	Residual chlorine load of the carcass	Yes	Water monthly chemical control	No	Yes	No	
3	Ink sealing receipt	Chemical	Inappropriate ink for foods	Yes	Control of ink documents	Yes			CCP1
4	Packing receipt	Biological	Dirty packings	Yes	Macroscopic control	Yes			
		Chemical	Inappropriate for foods (risk of migration)	Yes	Documents control	Yes			
		Physical	Presence of dust and foreign bodies	Yes	Macroscopic control	Yes			
5	Packing storage	Biological	Contamination due to deficient hygiene	Yes	Systematic sterilisation	No	Yes	No	
7	Stay	Biological	Dirty neat houses	Yes	Systematic clearing of neat houses	No	Yes	Yes	
8	Wait	None							
9	External washing	Biological	Microbial load of the head of the carcass with micro-organisms from water	Yes	Water monthly microbiological control	No	Yes	No	CCP2
		Chemical	Residual chlorine load of the head of the carcass	Yes	Water monthly chemical control	No	Yes	No	
10	Anaesthetisation with gun	Biological	Dirty cages of anaesthetisation	Yes	Clearing of cages	No	Yes	No	CCP3
11	Slaughter/blood-letting	Biological	Cross contamination of lancination and head caused by the workers or the animal's front members	Yes	Good practice Purification/disinfection of equipment Observance of health conditions	No	Yes	No	CCP4
12	Excoriation	Biological	Cross contamination of carcass caused by the skin, bung, messes, milk mainly with *E. coli* O157:H7	Yes	Good practice Purification/disinfection of equipment Observance of health conditions	No	Yes	No	 CCP5 CCP6
13	Head removal	Biological	Head contamination caused by the oesophagus or the workers and the equipment	Yes	Good practice Purification/disinfection of equipment Observance of health conditions	No	Yes	No	CCP7

(*Continues*)

Table 4.5 (*Continued*)

A/A CCP	Process stage	Kind of risk	Description of possible risks	Q1	Preventive actions	Q2	Q3	Q4	CCP
14	Cleaning and breast lancination/evisceration	Biological Biological Biological	Cross contamination of the carcass caused by the equipment/workers/insufficient clearing of the breast/rupture of the organs	Yes	Good practice Purification/disinfection of equipment Observance of health conditions	No	Yes	No	7 CCP8
15	Veterinary control (Appointed veterinary)								
16.	Washing	Biological	Microbial load of the head of the carcass with micro-organisms from water	Yes	Water monthly microbiological control	No	Yes	No	
		Chemical	Residual chlorine load of the head of the carcass	Yes	Water monthly chemical control	No	Yes	No	
17	Packing	Biological	Contamination caused by personnel	Yes	Observance of health conditions/GMP	No	Yes	No	8 CCP8
18	Freeze	Biological	Development of pathogenic due to inappropriate freezing (time, temperature, humidity)	Yes	Temperature control of the carcasses/control of the conditions and the refrigerator's function	Yes			9
			Contamination caused by unclean refrigerator		Systematic clearing of the refrigerator	No	Yes	No	CCP9
19	Washing								
20	Freeze								
21	Dispatch								
22	Brain extraction	Biological	Contamination caused by personnel	Yes	Observance of health conditions	No	Yes	No	CCP10
23	Head washing	Biological	Microbial load of the head of the carcass with micro-organisms from water	Yes	Water monthly microbiological control	No	Yes	No	CCP11
		Chemical	Residual chlorine load of the head of the carcass	Yes	Water monthly chemical control	No	Yes	No	
24	Head boning	Biological	Cross contamination caused by the workers and the equipment due to bad practice.	Yes	Good practice Purification/disinfection of equipment	No	Yes	No	CCP12
			Development of micro-organisms due to non-hygienic conditions in the deboning area	Yes	Temperature control of the space				
		Biological	Meat contact with dirty surfaces	Yes	Surfaces disinfection				

25	Packing	Biological	Contamination caused by personnel	Yes	Observance of health conditions/GMP	No	Yes	No	
26	Washing	Biological	Microbial load of the carcass with micro-organisms from water	Yes	Water monthly microbiological control	No	Yes	No	
		Chemical	Residual chlorine load of the carcass	Yes	Water monthly chemical control	No	Yes	No	CCP13
27	Dissection/removal of tail, fat and residues	Biological	Cross contamination caused by the workers and the equipment due to bad practice.	Yes	Good practice Purification/disinfection of equipment	No	Yes	No	CCP14
28	Veterinary control (Appointed veterinary)								
29	Temporary refrigeration of half-parts	Biological	Contamination caused by unclean refrigerator	Yes	Systematic clearing of the refrigerator	No	Yes	No	
30	Spinal cord removal/cutting in quadrants	Biological	Cross contamination caused by the workers and the equipment due to bad practice	Yes	Good practice Sterilisation/disinfection of equipment	No	Yes	No	CCP15
31	Refrigeration of suspect products	Biological	Development of pathogens due to inappropriate freeze (time, temperature, humidity)	Yes	Temperature control of the carcasses/control of the conditions and the refrigerator's function	Yes			CCP16
			Contamination caused by unclean refrigerator	Yes	Systematic clearing of the refrigerator	Yes			
32	Veterinary control (Appointed veterinary)								
33	Sealing	None							
34	Weighing–labelling		Malfunction of the balance		Periodical control of the balance and fixing of possible variation				
35	Freeze	Biological	Development of pathogens due to inappropriate freeze (time, temperature, humidity)	Yes	Temperature control of carcasses	Yes			CCP17
			Contamination caused by unclean refrigerator	Yes	Control of the conditions and the refrigerator's function Systematic clearing of the refrigerator	No	No	No	
36	Loading/dispatching under freeze	Biological	Alteration of the products due to their stay in inappropriate vehicles/refrigerators or due to their prolonged stay in high temperature	Yes	Observance of estimated conditions and preservation time.	Yes			CCP18
					Disinfection of the vehicles' cooling spaces and Systematic clearing	No	Yes	No	

Table 4.6 ISO 22000 Analysis worksheet for the determination of prerequisite programmes for the bovine carcass.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate	Is it feasible to evaluate them?	Do they contribute the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Cattle receipt	Yes	Yes	No	Yes	Yes
Veterinary inspection (Veterinary responsibility)					
Water licence	Yes	Yes	No	Yes	Yes
Ink sealing receipt	Yes	Yes	No	No	No
Packing receipt	Yes	Yes	No	No	No
Packing storage	Yes	Yes	No	Yes	Yes
Stay	Yes	Yes	No	Yes	Yes
Wait	Yes	Yes	No	Yes	Yes
External washing	Yes	Yes	No	Yes	Yes
Anaesthetisation with gun	Yes	Yes	No	Yes	Yes
Slaughter/blood-letting	Yes	Yes	No	No	No
Excoriation	Yes	Yes	No	No	No
Head removal	Yes	Yes	No	No	No
Cleaning and breast lancination/evisceration	Yes	Yes	No	No	No
Veterinary control (Appointed veterinary)	Yes	Yes	No	Yes	Yes
Washing	Yes	Yes	No	Yes	Yes
Packing	Yes	Yes	No	Yes	Yes
Freeze	Yes	Yes	No	No	No
Washing	Yes	Yes	No	Yes	Yes
Freeze	Yes	Yes	No	Yes	Yes
Dispatch	Yes	Yes	No	Yes	Yes
Brain extraction	Yes	Yes	No	Yes	Yes
Head washing	Yes	Yes	No	Yes	Yes
Head boning	Yes	Yes	No	Yes	Yes
Packing	Yes	Yes	No	Yes	Yes
Washing	Yes	Yes	No	Yes	Yes
Dissection/removal of tail, fat and residues	Yes	Yes	No	Yes	Yes
Veterinary control (Appointed veterinary)	Yes	Yes	No	Yes	Yes
Temporary refrigeration of half-parts	Yes	Yes	No	Yes	Yes
Spinal cord removal/cutting in quadrimers	Yes	Yes	No	Yes	Yes
Refrigeration of suspect products	Yes	Yes	No	No	No
Veterinary control (Appointed veterinary)	Yes	Yes	No	Yes	Yes
Sealing	Yes	Yes	No	Yes	Yes
Weighing–labelling	Yes	Yes	No	Yes	Yes
Freeze	Yes	Yes	No	No	No
Loading/dispatching under freeze	Yes	Yes	No	No	No

Table 4.7 Synoptical template of monitoring HAACP in the bovine carcass.

A/A CCP	No. stage	Process stage	Potential risks description	Preventive actions	Executed controls	Critical limits	Responsible	Corrective action	Responsible for corrective actions	Records – documents
1	3	Ink receipt	Inappropriate ink for foods	Suitability documents control	Suitability documents control	Every material without a suitability document is rejected	HACCP coordinator	Return of inappropriate materials	HACCP coordinator	File of incoming materials
2	4	Packing receipt	Inappropriate for foods	Suitability documents control	Suitability documents control	Every material without a suitability document is rejected	HACCP coordinator	Return of inappropriate materials	HACCP coordinator	File of incoming materials
3	11	Slaughter/blood removal	Cross contamination due to inappropriate techniques	Placement of carcass so as to avoid contamination from the head and the neck	The workers' technique is hourly controlled during the slaughter as well as during the placement of carcass. Control of the neck lancination Unannounced inspection of the processes once in a day	Every non-complying technique is considered unacceptable Skin lancination with contamination	Production manager	Location and holding of all carcasses till the last satisfactory control Counter-check of the neck lancination Recommendation to the workers	Production manager	Non Compliance, Corrective and Preventive Actions Registration Report
4	12	Excoriation	Cross contamination due to inappropriate techniques	Besides the first removed stripe of skin in the legs the rest of the skin is removed by internal dissection Removal of every visible contamination of the back part Effective removal of skin in the animal's sides in order to avoid contamination. Sterilisation of equipment to be used Avoidance of placement of carcass in front of the excoriation machine	The quality control manager inspects hourly the excoriation technique Two successive carcass are controlled hourly for possible contamination Unannounced inspection of the processes once in a day.	Every non-complying technique is considered unacceptable	Production manager	Removal of visible contaminations Direct compliance with GMP/ recommendation to the workers Location and holding of all carcasses till the last satisfactory control and clearing control	Production manager	Non Compliance, Corrective and Preventive Actions Registration Report

(*Continues*)

Table 4.7 (*Continued*)

A/A CCP	No. stage	Process stage	Potential risks description	Preventive actions	Executed controls	Critical limits	Responsible	Corrective action	Responsible for corrective actions	Records – documents
5	13	Head removal	Cross contamination due to inappropriate techniques	Cleaning of nails and ears before the inspection Clearing of the wound surface Binding of the oesophagus keeping the GHPs Elastic tape should be placed at the closest distance in the animal's stomach	The quality control manager audits the workers' technique for two successive animals every two hours Unannounced inspection once daily	No visible contamination before the head washing	Production manager	Compliance with the approved technique Location and hold of the carcass, the meat, the head and the tongues produced till the last satisfactory control. Inspection and clearing whenever is required. Information/ recommendation to the workers	Production manager	Non Compliance, Corrective and Preventive Actions Registration Report
6	14	Breast lancination, evisceration, cutting	Deficient breast clearing before its lancination Cross contamination due to inappropriate techniques Organ rupture	Breast lancination without contamination from bone particles and cartilage Clearing of every visible contamination caused by the breast and the sides before the opening of the abdominal area Evisceration 45 minutes after the slaughter The digestive system including the oesophagus is removed without rupture or puncture	The quality control manager inspects the evisceration technique every 2 hours. Lancination control Once a day four successive sections are controlled regarding the removal of visible cross-contamination. Daily unannounced inspection of processes and files	No visible contamination of the carcass and the offal Every non-complying technique is considered unacceptable	Production manager	Compliance with the approved technique Location and holding of the carcass, the head, and the tongues produced till the last satisfactory control. Inspection and clearing whenever is required. Information/ recommendation to the workers	Production manager	Non-Compliance, Corrective and Preventive Actions Registration Report

7	18	Freezing of offal	Development of psychrotrophic micro-organisms due to freezing in inappropriate conditions, transport delay in the fridge and fridge overload	Freeze inspection and safeguard of critical limits observance The cooling chambers are controlled and their temperature is constantly registered. Organs' ascertainment by an external associate once annually.	Control of 10% of offal 24 hours before the freeze start in order to detect the temperature achievement Control of temperature, relative humidity Batch numbers are controlled in order to detect their freeze in the limits of 1 hour. The receipt and registration of temperatures in the cooling chamber once in every shift All the thermometers are daily controlled. The thermometers calibration takes place annually from an approved external associate	Fridge temperature 0–2°C, relative humidity 85–90% Maximum admissible surface temperature of 3°C	Production manager Preservation facilities manager	Location and withdrawal of the cause of exceeding the critical limits Repeating control at the point in order to confirm the good function Engagement of all the products after the last satisfactory control. Rejection of bad products	Production manager Veterinarian	Daily record of temperatures Non-Compliance, Corrective and Preventive Actions Registration Report Verification documents.
8,9	31, 35	Freeze	Development of psychrotrophic micro-organisms due to freezing in inappropriate conditions, transport delay in the fridge and fridge overload	The production responsible inspects the freeze processes and ensures that the critical limits are followed. The freeze chambers of the carcass and the meat cuts are controlled and their temperature is constantly registered. Distances observance between the carcasses Organs' ascertainment by an external associate once annually	Control of 10% of offal 24 hours before the freeze start in order to detect the temperature achievement Control of temperature, relative humidity Batch numbers are controlled in order to detect their freeze in the limits of 1 hour. The receipt and registration of temperatures in the cooling chamber once in every shift	Meat temperature 7°C on the surface and 12°C internally (15 cm) Fridge temperature 0–2°C, relative humidity 85–90%	Production manager Preservation facilities manager	Location and withdrawal of the cause of exceeding the critical limits Repeating control at the point in order to confirm the good function. Engagement of all the products after the last satisfactory control. Rejection of bad products	Production manager	Non-Compliance, Corrective and Preventive Actions Registration Report Daily record of temperatures Verification documents

(*Continues*)

Table 4.7 (*Continued*)

A/A CCP	No. stage	Process stage	Potential risks description	Preventive actions	Executed controls	Critical limits	Responsible	Corrective action	Responsible for corrective actions	Records – documents
					All the thermometers are daily controlled. The thermometers calibration takes place annually by an approved external associate					
11	24	Loading/ dispatching	Product denaturation during the transport due to high temperature during the loading or due to inappropriate transport conditions	Evaluation – selection of appropriate transporters. Inspection of suitability (fridge temperature) and cleanliness of the conveyance	Extended control of the external picture of the batch number Temperature control (sampling) of the carcasses before the loading. Visual controls of cleanliness and temperature of the conveyances. Monthly microbiological control of the final product from approved external associate	*T* 0–2°C	Production manager	Hold the lot number of products which do not comply to specs. Extension of stay in the fridges till the achievement of the desired temperature, if this is required	Production manager	Registration file of microbiological controls

Table 4.8 Comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with prerequisite programme (PRP) for bovine carcass.

Process stage	CCPs of HACCP	Prerequisite programme (ISO 22000)	CCPs of ISO 22000
Cattle receipt		Yes	
Veterinary inspection (Veterinary responsibility)			
Water licence		Yes	
Ink sealing receipt	1	No	1
Packing receipt		Yes	
Packing storage		Yes	
Stay		Yes	
Wait		Yes	
External washing	2	No	
Anaesthetisation with gun	3	No	
Slaughter/blood-letting	4	No	2
Excoriation	5	No	3
Head removal	6	No	4
Cleaning and breast lancination/evisceration	7	No	5
Veterinary control (Appointed veterinary)		Yes	
Washing		Yes	
Packing	8	No	
Freeze	9	No	6
Washing		Yes	
Freeze		Yes	
Dispatch		Yes	
Brain extraction	10	No	
Head washing	11	No	
Head boning	12	No	
Packing		Yes	
Washing	13	No	
Dissection/removal of tail, fat and residues	14	No	
Veterinary control (Appointed veterinary)		Yes	
Temporary refrigeration of half-parts		Yes	
Spinal cord removal/cutting in quadrimers	15	No	
Refrigeration of suspect products	16	No	7
Veterinary control (Appointed veterinary)		Yes	
Sealing		Yes	
Weighing–labelling		Yes	
Freeze	17	No	8
Loading/dispatching under freeze	18	No	9

Washed carcasses are chilled down to between 2 and 4°C overnight.

In general, microbiological contamination contact time associated with fresh or 'hot' carcass surfaces (i.e. before chilling) is relatively short in duration, whilst micro-organisms associated with carcasses following chilling may have been present on tissue surfaces for much longer (e.g. 24–72 hours) (Firstenberg-Eden, 1981). Other suggested negative effects of spray-washing red meat animal carcasses with water include: (i) elevated tissue surface moisture resulting in increased establishment on the tissue surfaces and proliferation of micro-organisms, (ii) entrapment, embedding or driving bacteria into tissues, thereby providing a physical barrier against subsequent decontamination applications, (iii) reduced competitive inhibition resulting from reductions in population densities of commensal microflora and (iv) redistribution of spreading of a localised microbiological population over a much larger area (Cabedo *et al.*, 1996).

Pearce *et al.* (2004) obtained aerobic mesophilic counts, coliform and coliform resuscitation counts by swabbing 50 cm^2 areas at three sites (ham, belly and neck) on pig carcasses, after each of the seven stages of the slaughter/dressing process (bleeding, scalding, dehairing, singeing, polishing, evisceration and chilling). In most cases, there were no statistical differences ($p > 0.05$) between the counts derived by these three methods. Reductions in counts at individual sites were observed after scalding (3.5 $\log_{10}$ cfu [colony

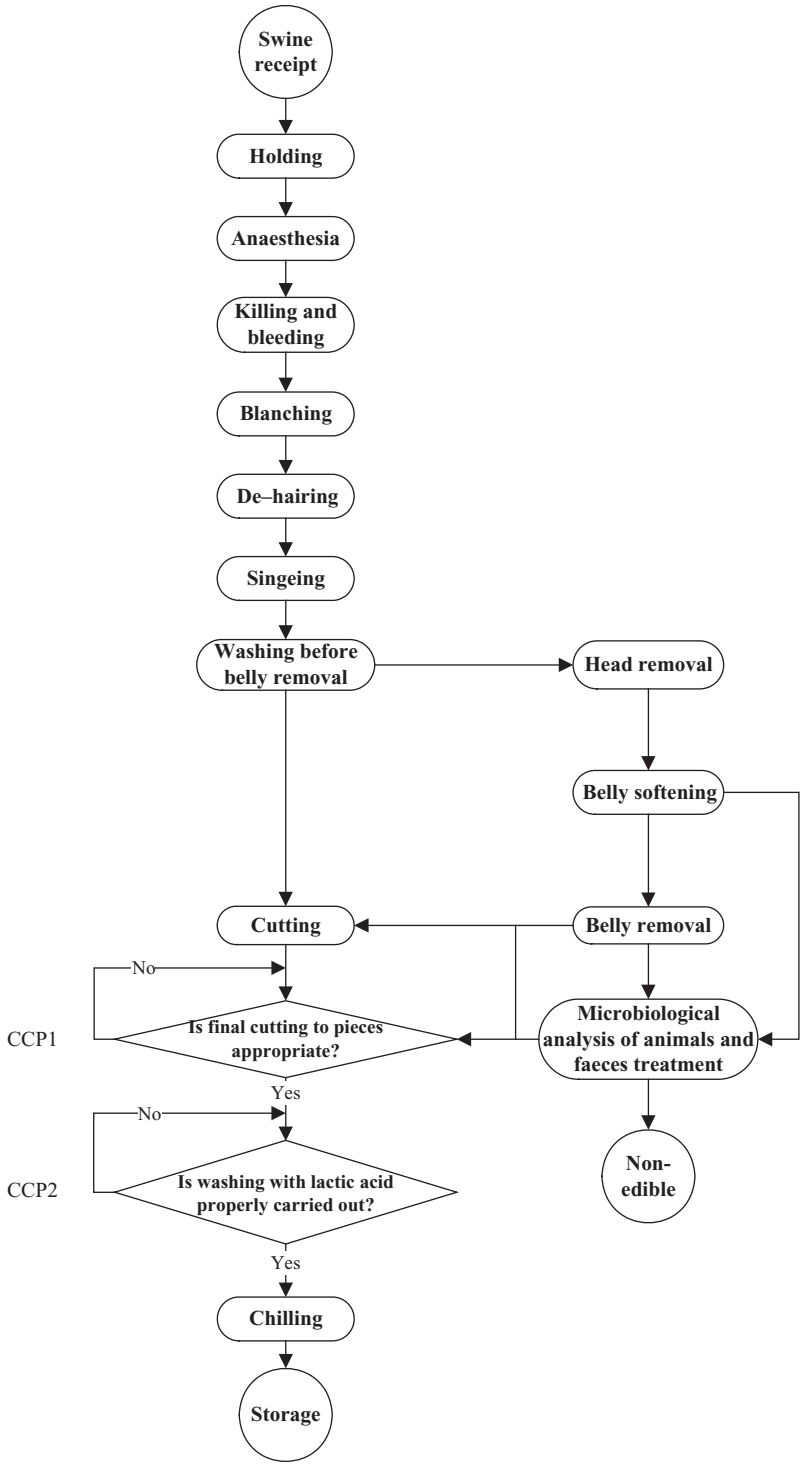

Fig. 4.2 Flow diagram for swine carcass.

Table 4.9 Implementation of HACCP in a pork carcass (http://www.das.cas.psu.edu-HACCP-CCP-PORKslaughter.pdf.url).

CCP	Critical limits	Control measures	Corrective action
CCP1 (Reduction of pathogens)	Non-visible faecal contamination on the carcass	Control of each carcass for a visible contamination by personnel	Removal of visible contamination, washing of carcass with lactic acid solution
CCP2 (Reduction of pathogens)	The whole carcass should be sprayed with a 2% lactic acid solution	Control of the concentration of lactic acid solution before its application	Washing of carcass with the right solution of lactic acid

forming unit]/cm^2), and singeing (2.5 $\log_{10}$ cfu/cm^2). Increases in counts at individual sites were observed after dehairing (2 $\log_{10}$ cfu/cm^2) and polishing (1.5 $\log_{10}$ cfu/cm^2). The incidence of *Salmonella* on pig carcasses was also obtained by swabbing the outside surfaces of 100 half carcasses. Information on the incidence of *Salmonella* in scald tank water (108 samples) was also investigated. Carcass swabs and scald tank water were examined for the presence of *Salmonella* using standard enrichment methods. *Salmonella* were detected on 31% of carcasses immediately after bleeding, 7% of carcasses immediately after dehairing and evisceration, and 1% of carcasses immediately after scalding. Serovars included *Salmonella typhimurium*, *Salmonella hadar*, *Salmonella infantis* and *Salmonella derby*. No *Salmonella* were recovered from samples of scald tank water.

Since scalding reduces drastically the bacterial numbers, and the incidence of pathogens such as *Salmonella*, it should be considered as a CCP within a HACCP system for this type of slaughterhouse. This study also reported that coliform resuscitation counts were significantly higher than the coliforms after scalding, indicating that bacteria on carcasses are stress damaged during scalding (Pearce *et al.*, 2004).

The data also showed a reduction in the incidence of *Salmonella* from 7 to 0% as a result of singeing (Pearce *et al.*, 2004). If singeing is to be a CCP in HACCP schemes, it is essential to standardise the process by defining conditions such as the operating temperature, treatment duration etc.

Sheridan (2000) stated that chilling rates are influenced by intrinsic factors such as carcass weight, temperature, and fat cover, and extrinsic factors including chill temperature, air speed, relative humidity and carcass spacing. The general characteristics of meat products from pork are summarised in Table 4.10 and the determination of CCPs for swine carcasses, the ISO

Table 4.10 General characteristics of meat products from pork.

Products	Fresh and frigid meat products from pork (meat cuts, meat roll, pork, schnitzel, faggot, steak, meat skewer)
General lineaments	No content in preservatives It has suffered superfreezing (some of them)
Packing	A′packing: nylon (vacuum or not) Polystyrene discs Second packing: paper packing case
Use	Sale in restaurants, supermarkets
Shelf life	Fresh max. 3 days Frigid products from meat cuts till 1 year Frigid products from meat till 9 months
Storage and transportation instructions	Under freeze 0–2°C Freezing −18°C If defrosted they should not be frozen Consumption after a thermal process (T at the centre up to 72°C)
General specifications	(1) Products in compliance with the directives: 93/43/EEC, 91/497/EEC, 91/498/EEC, 64/433/EEC, 71/118/EOK, 94/65/EEC, 92/116/EEC, P.D. 599/85 and the Code of Food and Beverage (2) Internal Regulations of the company

Table 4.11 Determination of critical control points for swine carcasses.

A/A CCP	Step	Do control measure(s) exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of a hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable levels?	Will a subsequent step eliminate identified hazards or reduce likely occurrence to an acceptable level?	CCP
1	Packing receipt	Yes	Yes	—	—	CCP1
2	Ink receipt	Yes	Yes	—	—	CCP2
3	Slaughter/blood removal	Yes	Yes	—	—	CCP3
4	Excoriation	Yes	Yes	—	—	CCP4
5	Residues removal/cleaning and dissection of the sternum/evisceration	Yes	Yes	—	—	CCP5
6	Freezing of livers, heads	Yes	Yes	—	—	CCP6
7	Loading/dispatching	Yes	Yes	—	—	CCP7

22000 analysis worksheet for the determination of PRPs for the swine carcasses, the synoptical template of monitoring HACCP in the swine slaughter raw and the comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with PRPs for swine slaughter raw are given in Tables 4.11–4.14.

4.8 FOOD IRRADIATION

The increase in food poisoning incidences and the resulting socioeconomic effects on the human population, led the public health authorities to re-evaluate the quality assurance procedures associated with food irradiation.

The implementation of a HACCP-based process to the risks in the food chain shows there is a need for the application of a cold disinfection method as a control measure in food processing and more specifically fresh foods or minimally processed foods. Irradiation can be applied in poultry, meat and meat products. Irradiation could be a CCP. It has the ability to reduce the vegetative spores of pathogenic bacteria as well as parasites. It is a safe technology, recognised by

Table 4.12 ISO 22000 Analysis worksheet for the determination of prerequisite programmes for the pork slaughter raw.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Packing receipt	Yes	Yes	No	Yes	Yes
Ink receipt	Yes	Yes	No	Yes	Yes
Slaughter/blood removal	Yes	Yes	No	No	No
Excoriation	Yes	Yes	No	No	No
Residues removal/cleaning and dissection of the sternum/evisceration	Yes	Yes	No	No	No
Freezing of livers, heads	Yes	Yes	No	Yes	Yes
Loading/dispatching	Yes	Yes	No	Yes	Yes

Table 4.13 Concentrative template of monitoring HACCP in the swine carcasses.

A/A CCP	No. stage	Process stage	Potential risks description	Preventive actions	Executed controls	Critical limits	Responsible	Corrective action	Responsible for corrective actions	Files – documents
1	3	Packing receipt	Inappropriate for foods	Suitability documents control	Weekly control of the incoming materials	Every material without a suitability document is rejected	HACCP coordinator	Return of inappropriate materials	HACCP coordinator	Receipt file
2	5	Ink receipt	Inappropriate ink for foods	Suitability documents control	Weekly control of the incoming materials	Every material without a suitability document is rejected	HACCP coordinator	Return of inappropriate materials	HACCP coordinator	Receipt file
3	10	Slaughter/blood removal	Cross contamination due to inappropriate techniques	Carcass placement so as to avoid contamination from the head and the neck	The workers technique is hourly controlled during the slaughter of two successive animals as well as during the placement of the carcass. Control of neck lancination Unannounced inspection of the processes daily	Every non-complying technique is considered to be unacceptable. Skin lancination without contamination	Production supervisor	Holding of all carcasses till quality control proves satisfactory Counter-check of the neck lancination Recommendation to the workers	Production supervisor	Non-Compliance, Corrective and Preventive Actions Registration Report
4	11	Excoriation	Cross contamination due to inappropriate techniques	Besides the first removed stripe of skin in the legs the rest of the skin is removed by internal dissection Removal of every visible contamination of the back part Effective removal of skin in the animal's sides in order to avoid contamination. Avoidance of contamination caused by the breast – equipment sterilisation Avoidance of placement of the carcass in front of the excoriation machine	The quality control manager audits hourly the excoriation technique Two successive carcasses are inspected hourly for possible contamination Unannounced inspection of the processes daily	Every non-complying technique is considered to be unacceptable	Production supervisor	Removal of visible contaminations Direct compliance with the GMP/ recommendation to the workers Location and holding of all the carcasses till the last satisfactory control and clearing control	Production supervisor	Non-Compliance, Corrective and Preventive Actions Registration Report

(*Continues*)

Table 4.13 (*Continued*)

A/A CCP	No. stage	Process stage	Potential risks description	Preventive actions	Executed controls	Critical limits	Responsible	Corrective action	Responsible for corrective actions	Files – documents
5	12	Residues removal/ cleaning and dissection of the sternum/ evisceration	Breast deficient clearing before its lancination Cross contamination due to inappropriate techniques Organ rupture	Breast lancination without contamination from particles of bone and cartilage Clearing of every visible contamination caused by the breast and the sides before opening of the abdominal area. Evisceration 45 minutes after the slaughter The digestive system including the oesophagus is removed without rupture or puncture	The production manager controls every 2 hours the evisceration technique Lancination control Once a day four successive half-parts are inspected regarding the removal of visible cross-contamination. Unannounced daily inspection of the processes and the files.	No visible contamination of the carcass and the offal No non-complying technique	Production supervisor	Compliance with the approved technique. Location and holding of the offal produced till the last satisfactory control. Inspection and clearing whenever is required. Information/ recommendation to the workers	Production supervisor	Non-Compliance, Corrective and Preventive Actions Registration Report
6	18	Freezing of livers, heads	Development of microbes due to inappropriate freeze conditions, transport delay in the fridge and fridge overload	The production manager inspects the freeze processes and ensures that the critical limits are followed. The freezing chambers of the carcasses and the meat cuts are controlled and their temperature is constantly registered.	Control of 10% of the offal 24 hours before the freeze start Batch numbers of the carcasses are inspected in order to detect their freeze in the limits of 1 hour. All the results are registered and signed. These records of the cooling chambers of carcass are reviewed once per shift and the recording of their temperatures is audited. The maintenance person will verify the accuracy of the cooling chambers for the carcass. This person will control daily all the thermometers and will calibrate them whenever required	All the offal should be cooled within 1 hour after the cutting of the carcass. Fridge temperature 0–2°C, relative humidity 85–90%, speed of air movement 0.1–0.2 m/second. Maximum admissible temperature 3°C	Production manager Equipment maintenance manager	Location of the deviation cause and prevention of repetition. Repair of any damage fridges	Responsible person	Non-Compliance, Corrective and Preventive Actions Registration Report Fridges Record

7, 8	21, 25		Development of psychrotrophic micro-organisms due to inappropriate freeze conditions, transport delay in the fridge and fridge overload	The production manager inspects the freeze processes and ensures that the critical limits are followed. The freezing chambers of the carcasses and the meat cuts are controlled and their temperature is constantly registered. Recording of distances between the carcasses	Control of 10% of the offal 24 hours before the freeze start in order to detect the temperature achievement. Control of temperature, relative humidity and speed air when the chamber is full. Control of batch numbers in order to detect their freeze in the limits of 1 hour. The receipt and registration of temperatures in the cooling chamber once in every shift. The maintenance person will verify the accuracy of the cooling chambers for the carcass. All the thermometers are daily controlled. The thermometers calibration takes place annually by an approved external associate	Fridge temperature 0–2°C, relative humidity 85–90%, speed of air movement 0.1–0.2 m/second. Meat temperature 7°C on the surface and 12°C internally (15 cm)	Production supervisor Preservation facilities manager	Location and withdrawal of the cause of excess of critical limits. Repeating control at the point in order to confirm good function Engagement of all the products after the last satisfactory control. Rejection of bad products	Production supervisor	Non Compliance, Corrective and Preventive Actions Registration Report (ΕΛ-02–00-01) Fridges Record
9	26	Loading/ dispatching	Product denaturation during the transport due to high temperature during the loading or due to inappropriate transport conditions	Evaluation – selection of appropriate transporters Inspection of suitability (fridge temperature) and cleanliness of the conveyance	Extended control of macroscopic control of batch number Temperature control (sampling) of carcasses before the loading Visual controls of cleanliness and temperature of the conveyances. Monthly microbiological control of the final product from approved external associate	Temperatures 7°C or lower for the meat and 3°C for the offal	Production supervisor	Hold of the batch number of non-conforming products Extension of stay in the fridges till the achievement of the desired temperature, if this is required	Production supervisor	Microbiological controls file

Table 4.14 Comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with prerequisite programmes (PRPs) for swine carcasses.

Process stage	CCPs of HACCP	Prerequisite programme (ISO 22000)	CCPs of ISO 22000
Packing receipt	1	No	—
Ink receipt	2	No	—
Slaughter/blood removal	3	No	1
Excoriation	4	No	2
Residues removal/cleaning and dissection of the sternum/evisceration	5	No	3
Freezing of livers, heads	6	No	—
Loading/dispatching	7	No	—

Codex Alimentarius. At the time of writing 40 countries allow the use of irradiation in one or more products; 12 countries use irradiation technology to control pathogens in poultry; 8 for meat and 13 for fish and seafood.

One of the newly emerging technologies for ensuring the microbiological safety of meat is radiation processing. In addition to spoilage bacteria, meat products may contain parasites and pathogenic bacteria, which could be eliminated by irradiation. The radiation doses required to inactivate 90% of the colony forming units of the common foodborne pathogens associated with meat and meat products are in the range of 1–4 kGy (Thayer *et al.*, 1993).

There are several reports dealing with the radiation processing of meat products such as bacon, ham (Weirbicki and Heilgman, 1980), sausages (Kiss *et al.*, 1990), beef burgers (Dempster *et al.*, 1985).

The effect of radiation processing on the shelf life and safety of some ethnic Indian meat products like chicken chilly, mutton shammi kababs and pork salami during chilled storage was investigated by Kanatt *et al.* (2005). Radiation processing resulted in dose-dependent reduction in microbial counts. A dose of 3 kGy was found to be optimal for shelf-life extension. In all the three irradiated (3 kGy) meat products the shelf life was extended by more than two weeks at 0–3°C compared to the corresponding non-irradiated samples. *Staphylococcus* spp. were completely eliminated by irradiation at a dose of 2 kGy. Some increase in lipid peroxidation on irradiation was observed as measured by the TBA assay but it did not affect the sensory attributes of the product.

4.8.1 Applications of irradiation

4.8.1.1 Applications in poultry

Irradiation is the only physical process capable of eliminating *Salmonella* and *Campylobacter* from poultry. These micro-organisms may be present due to inappropriate cooking, abuse of time and temperature of cooking or preservation, recontamination following cooking due to contact with dirty surfaces, hands or tools. In total 12 countries have recognised the use of irradiation (http://www-pub.iaea.org/MTCD/publications/PDF/Newsletters/SSDL-NL-37.pdf).

4.8.1.2 Applications in meat and meat products

Meat and meat products may be contaminated by pathogenic micro-organisms such as *Salmonella*, *E. coli* O15 and *Yersinia* as well as parasites such as *Toxoplasma gondii*, *Taenia solium* and *Trichinella spiralis*. Another problem is that some people prefer to consume raw or lightly cooked. This results in a great hazard for health unless a process such as irradiation is applied to the meat of meat products.

Raw meat can be irradiated at low doses to eliminate pathogenic bacteria and inactivate parasites. Eight countries use irradiation of fresh or processed meat to disinfect and control parasites.

4.8.2 Critical irradiation limits

Critical limits in irradiated foods are the doses where removal of pathogenic bacteria or control of parasites is accomplished. Irradiation in median doses (3–7 kGy) effectively destroys vegetative cells of all pathogenic bacteria. Parasites require even smaller doses <1 kGy.

The Codex Alimentarius Commission considers that the application of an irradiation dose in foods up to 10 kGy is acceptable, whereas WHO considers the application of an irradiation dose even higher than 10 kGy in foods, safe and nutritionally acceptable when foods are manufactured under GMP (Molins *et al.*, 2001). Radiation treatment at doses of 0.15–0.7 kGy under specific conditions appears to be effective also for control of many foodborne parasites, thereby making infested foods safe for human consumption (Farkas, 1998).

Irradiation can sterilise or kill insects, and kill fungi and some bacteria that live in foods. These foods do not become radioactive, but it is believed that there are risks and drawbacks to the use of this technology:

- Chemical by-products called 'unique radiolytic products' (URPs) are created in foods by irradiation. Some scientific studies carried out on URPs link health risks with the consumption of irradiated foods.
- Irradiated foods are less nutritious than fresh foods because radiation damages some vitamins, amino acids and fatty acids.
- Irradiation will not replace many additives commonly used in processed foods. In fact, some additives need to be used in combination with irradiation to control undesirable side-effects.
- Irradiation of poultry is being proposed as a means for preventing *Salmonella* food poisoning. In fact, less than 20% of *Salmonella*-poisoning cases can be traced back to poultry.
- Irradiation can actually cause food poisoning since treated foods may be contaminated but appear fresh. Micro-organisms which normally cause meat to look or smell spoiled may be killed by irradiation, yet more resistant bacteria, such as the one causing botulism food poisoning, may survive. Some organisms may even mutate when irradiated, forming new, more radiation-resistant strains.
- Aflatoxin is a toxic and carcinogenic (cancer-causing) substance produced by bacteria. Irradiation of these bacteria actually causes them to produce more aflatoxin.
- Increased use of food irradiation will increase occupational and environmental hazards. The level of gamma radiation inside an operating irradiation facility is anywhere from ten to hundreds of times the level that would kill a human in a single short exposure

(Hayashi and Todoriki-Suzuki, 2001; http://www.sierraclub.ca/national/action-alert/nuclear-energy/food-irradiation-alert.html).

4.9 NON-ACID TECHNOLOGIES FOR MEAT DISINFECTION

The application of the HACCP system helps to demonstrate whether microbiological criteria are met. This ability to monitor the microbiological status of meat products has allowed the development and application of disinfection methods in meat. This provides industry with the tools to use microbiological criteria and supports the dream of delivering to the consumers' products devoid of micro-organisms.

The selection of disinfection methods is based on the need for disinfection, the cost, resources' availability and intended final use of the food:

(A) Washing and removal of the tail of live animals aids in the reduction of contamination sources during slaughtering.
(B) Chemical dehairing in bovine carcasses before skin removal reduces the visible contamination.
(C) Local cleaning with vapour equipment, hot water or vacuum during bovine slaughtering reduces the natural contamination residence.
(D) Washing or spraying in bovine carcasses reduces the contamination of carcasses during removal of offal.
(E) Chemicals such as chlorine or triphosphoric sodium are effective in poultry disinfection and are volatile so that they can be removed from the food without considerable effort.
(F) Application of hot water ($>74^{\circ}$C) or steam inactivates bacteria and reduces the possibility of bacterial growth.
(G) Steam sterilisation of bovine carcasses during the slaughter process after washing of the animals followed by exposure to cold water before chilling, reduces the number of micro-organisms coming from a natural infection.

The above methods can be applied either alone or in combination. The best disinfection practices tend to fail without the proper design, appropriate hygiene, GMPs and GHPs (Sofos and Smith, 1998).

4.10 QUANTITATIVE RISK ASSESSMENT

The use of highly structured and very sophisticated descriptive epidemiological models covering the whole period from farm to table, can be considered as a promising solution for the assessment of microbiological hazards in health relevant to processing and meat consumption. Using these models hazards can be quantified (Berends *et al.*, 1996).

Quantitative risk assessment (QRA) is a methodology used to organise and analyse scientific information so that the severity and frequency of occurrence can be mitigated. Moreover, it can contribute in the recognition of stages in production, distribution, handling and food consumption that may increase the potential hazard of food poisoning and it can also aid in focusing on effective ways to reduce the hazard of causing food poisoning (Cassin *et al.*, 1998).

It is important to recognise the potential hazards during HACCP implementation so that measures can be taken and the effect of these measures can be quantified to evaluate the existence of hazards in the final products (Hoornstra *et al.*, 2001).

The application of risk assessment is restricted due to the uncertainty and ignorance of the effects from the application of hygienic measures in handling during manufacturing and processing (Cassin *et al.*, 1998).

The method consists of the following steps:

1. Hazard recognition: the effects of the most important hazards are observed in the final product. Dangers are categorised based on product type and processing procedure.
2. Risk characterisation: qualitative and/or quantitative assessment of the stage of danger associated with physical, chemical and microbiological factors that might be present in food. Based on the critical limits characterisation takes place. Concentrations over the limits increase the possibility of causing food poisoning. If criteria are absent they should be identified.
3. Exposure assessment: the quantitative or qualitative assessment of the possible uptake of physical, chemical and biological factors through the foods. Dangerous uptake points are considered the raw materials, processing steps and environment, as well as the composition, packaging and storage conditions of the product.
4. Risk assessment: it is the combination of the risk characterisation and the exposure assessment that leads to the risk assessment, i.e. the possibility of presence of dangerous factors in foods, e.g. microorganisms or their residual toxins in such quantities that could cause food poisoning.

4.11 APPLICATION OF QRA

Outbreaks of *E. coli* O157:H7 in raw fermented sausages with high pH and low water activity are as follows:

1. Hazard recognition: *E. coli* O157:H7 is the most important danger and could be relatively resistant to acids.
2. Risk characterisation: since no data exists on the infective dose of *E. coli* O157:H7 the dose of *Shigella dysenteriae* is used as it has a similar mechanism of infection.
3. Exposure assessment: the dangers are recognised initially in the food chain. The most important are the growth and concentration of *E. coli* O157:H7 in faeces of cattle, contamination during slaughtering, reduction during fermentation and storage and the quantity consumed. The possibility of the occurrence of *E. coli* O157:H7 varies between 0 and 1000 cfu/g. It is possible not to detect *E. coli* O157:H7 in all sausages. During fermentation and storage a reduction in bacterial population was observed and hence a reduction in the cases.
4. Risk assessment: due to the high variability between individuals of the dose–reaction profile, the variability of risk is also high.
5. Risk management: due to the low percentage of contaminated sausages and the low number of bacteria found in the sausages, there is no need to determine a level which is the maximum acceptable (Hoornstra *et al.*, 2001).

4.12 ASSOCIATION OF *SALMONELLA* TYPES IN MEAT AND THE CAUSE OF FOOD POISONING

Samples of four different products of animal origin (bovine, pork, chicken, turkey) and the respective raw ground products were investigated before application of HACCP. *Salmonella* spp. was found in the carcasses as well as in the respective raw, ground products.

The most common types of *Salmonella* found in products before HACCP application differ from those that most frequently cause food poisoning in humans. This could be due to the fact that certain types such as *Salmonella typhimurium* and *Salmonella enteritidis* are found less frequently in animals or possibly they may be more pathogenic in humans than in animals (Schlosser *et al.*, 2000).

4.13 HACCP, IRRADIATION AND CHEMICAL METHODS TO REDUCE THE RISK OF FOOD POISONING

The HACCP system is specifically designed to prevent unsafe conditions. At every processing stage, hazards are identified that may produce undesirable conditions, CCPs, identification is followed by the establishment of procedures for food safety, followed by implementation of these control processes. Finally, microbiological analysis is carried out to investigate the effectiveness of the system.

Irradiation consists of γ-radiation or electron beam processing of foods to destroy the majority of the most common bacteria in foods and more specifically in poultry.

The chemical-processing methods are used to reduce or eliminate the pathogenic bacteria and apply widely in processing units. Use of 10% triphosphoric sodium reduces *Salmonella* levels in poultry without affecting the final raw or cooked product.

More than three-fourths of the respondents were willing to spend 5 cents (c)/pound (lb) to buy products where a HACCP system is implemented despite products where other systems were operating.

The median willingness of the respondents to pay more for products where a HACCP system is implemented (5.6 c/lb) and irradiation (4.5 c/lb) was higher than those where chemical methods apply (0.7 c/lb).

Nutritionists agree with the application of a HACCP system in products of animal origin to reduce the hazards due to pathogenic bacteria in processing units. They also agree with irradiation, which could lead to the rapid development of the method (Giamalva *et al.*, 1998).

4.14 BENEFITS OF HACCP IMPLEMENTATION IN THE MEAT INDUSTRY

Regarding benefits of implementing and operating the HACCP system in meat-processing plants, 17 enterprises with HACCP in full operation were included in the analysis of the costs, benefits and difficulties of implementation. The respondents were presented with a list of six different costs of implementing HACCP and were asked to rank a list of benefits from 1 to 11, with 1 being very important and 11 being unimportant. The main benefit was a reduction in microbial counts (average ranking of 2.6) which can be considered as tangible benefit, followed by clientele and product benefits, such as the ability to attract new customers (2.8), access to international markets (2.9), and prolonging product shelf life (2.9) which are less tangible (Henson *et al.*, 1999). The levels of HACCP implementation, costs of implementation and operation, and benefits of implementation for the Mexican meat industry have been analysed by Maldonado *et al.* (2005). One hundred and sixty federal inspection type (TIF) enterprises were surveyed, with a 58% response rate. Only 18% of the TIF enterprises interviewed had totally adopted HACCP, while 20% did not have an interest in adoption. The norm of ISO 9000 appeared to be an intermediate step in HACCP implementation. The results show that investment in new equipment and microbiological tests of products accounted for most of the implementation and operational costs, respectively.

The local public interest has not been the major reason for the implementation of HACCP systems in the Mexican meat industry. Implementation of HACCP has been to meet requests from international markets and very specific domestic niches. If the Mexican meat industry waits for local public demand to adopt HACCP, it might be too late and the foreign industry can be treated as a threat to the Mexican industry. Thus, in a globalised trade to avoid HACCP implementation until local demand arises may curtail local meat industry production. In the short term, Mexico continues to play an important role in the meat trade, particularly on the American continent.

According to the pathogen reduction–hazard analysis and critical control (PR-HACCP) rule for the production of meat and poultry products, the safety of meat and poultry products needs to be achieved by a 'Farm to Table' application of control measures. However, in seeming disregard of reality, this rule applies only to slaughter/packing and further processing plants. Live animals enter one end of the slaughter plant; raw products exit the other end. The fundamental control of the safety of raw meat and poultry products must be implemented further down the Farm to Table chain where definitive control measures such as cooking or irradiation can be applied and managed.

However, failure to conform to the USDA's criteria in a single round of product sampling does not mean that action would be taken against the product or against the packing plant. According to White Paper, the plant will be most likely granted an indeterminate period of time in which to review and modify its HACCP plan (EU, 2000; White Paper available at: http://ec.europa.eu/dgs/health_consumer/library/pub/pub06_en.pdf.).

Upon acceptance of the modified HACCP plan by USDA, a second round of a number of daily samples will be taken by the agency at some later time which they will give notice of as part of the procedure. Failure to conform to the stated criteria during the second round of sampling will re-trigger the cycle until a third round of sampling was completed. If a plant fails three consecutive rounds of *Salmonella* testing, the agency has the authority under this rule to withdraw inspection, thereby closing the packing plant. Sometimes the agency does not invoke its plant closure authority until the plant has failed four consecutive rounds of sampling.

The hallmarks of a valid HACCP plan were that monitoring procedures and corrective actions, in so far as possible, should be taken in real time, and should be as continuous as possible.

Moreover, microbial control in meat packing plants can be effectively verified by simple microbiological tests, such as aerobic plate counts. Under these conditions, a packing plant could rely on documented

conformance to its HACCP plan as assurance that its products are safe (Sperber, 2005).

Standards of hygiene at supplying slaughterhouses should be monitored by regular inspection and auditing programmes conducted by meat manufacturers. Such raw material supplier auditing needs to stress the importance of minimising contamination with *E. coli* (Bell and Kyriakides, 1998). Following the reviews of the *E. coli* O157 outbreaks, a full investigation was conducted by an independent committee who made some excellent recommendations regarding the control of the hazard in slaughterhouses (Bell and Kyriakides, 2000; Pennington, 1997). Foremost among these was the implementation of a HACCP-based approach to the slaughter of animals, involving the adoption and implementation of common sense approaches to limiting the opportunity for contamination and cross-contamination. Some of the other points raised were (i) training of operatives in food hygiene, (ii) provision of adequate space between carcasses on conveyor lines and (iii) design of conveyor to avoid contact with walls and floors (Corry *et al.*, 1995).

The important role of good hygienic practices for controlling *Salmonella* throughout animal husbandry, slaughtering processes and the further processing of raw meat and raw meat products has long been well understood and was well addressed by a World Health Organisation Expert Committee on Salmonellosis Control (World Health Organisation, 1988). The raw material and other incoming are given in Table 4.15, the raw material risk analysis is summarised in Table 4.16 and the risk assessment of raw materials is given in Table 4.17. The supporting functions of meat and the concentrative templates of HACCP monitoring of various products are given in Tables 4.18 and 4.19, respectively.

Table 4.15 Raw material and other incoming materials.

Raw materials and other incoming	Descriptions/comments
Meat	
Pork	Fresh and frozen
Lard	
Skin	
Edible cases	
Seasonings	
Pepper	Packed/standardised
Origan	
Red pepper	
Salt	
Garlic	
Additives/colours	
Nitrous	Packed/standardised
Ascorbic	
Phosphates	
Sugars	
Potassium sorbate	
Starch	
Vegetables	
Leek	Bore
Pepper	
Onion	
Water	
Packing materials	
Cases of collagen and cellulose	Suitable for foods
Bowels	
Nylon	
Cellophan	
Polystyrene discs	
Paper packages	

4.15 CHEMICAL HAZARDS

The chemical dangers in raw meat are antibiotics, veterinary drugs, mineral supplements, vitamin supplements, protein supplements, growth factors, digestion enhancers, preservatives, antioxidants, disinfectants and detergents (the last four normally associated with post-slaughter activities) (Ropkins *et al.*, 2003). The inorganic chemical hazards are arsenic, mercury, cadmium, zinc etc. (Karouna-Renier *et al.*, 2007).

4.16 CCP IDENTIFICATION

Franco *et al.* (1991) identified a number of potential CCPs associated with the slaughter of cattle, swine, and sheep, including pre-slaughter transport, slaughter and evisceration. Hathaway and McKenzie (1991) recommended the routine inspection of carcasses and offals as a means of minimising both microbiological and chemical contamination.

Tompkin (1990) discussed the application of HACCP to both raw and processed meat products and later produced generic HACCP procedures for meat products (Tompkin, 1994). Tompkin (1994) also suggested that the effectiveness and efficiency of HACCP justified its use by the meat industry, regardless of legal status. The New Zealand Ministry of Agricultural identified a number of limitations to existing raw meat HACCP procedures and addressed these problems by developing a generic template for raw meat HACCP (Lee and Hathaway, 1998; NZ MA, 1997).

4.17 BEEF

Some of the identified steps are specific to raw beef production (e.g. the post-slaughter-processing procedure),

Table 4.16 Raw material risk analysis.

Feedstock	Biological hazard	Chemical hazard	Physical hazard
Meat and by-products	Presence of pathogenic micro-organisms: *Listeria monocytogenes*, *Yersinia enterocolitica*, *Campylobacter jejuni*, *Salmonella* spp., *Stahylococcus aureus*, *E. coli* (O157:H7), *Shigella* spp. Spore formers: *Clostridium perfringens*, *Clostridium botulinum*, *Bacillus cereus* Parasites: porc *Trichinella spiralis* and *Toxoplasma gondii* Beef: *Cysticercus bovis* and *Toxoplasma gondii* Increased temperature during the receipt (>4°C or >−17°C) entails a risk of development and multiplication of pathogenic micro-organisms	Remains of antibiotics Presence of mycotoxins Pesticides and heavy metals: increased residues	Foreign bodies Needles Metals and bones slivers
Vegetables	*Escherichia coli*, *Staphylococcus aureus*, *Clostridium perfringens*, *Shigella* spp., *Listeria*, *Salmonella* spp.	Pesticides: increased residues	Foreign bodies
Seasonings	Increased humidity entails a risk of development and multiplication of pathogenic micro-organisms Non-sporeformers: *Salmonella* sp., *Listeria monocytogenes*, *E. coli* Spore formers: *Clostridium perfringens*, *Bacillus cereus* Mycotoxins	Pesticides and heavy metals: increased residues	Foreign bodies
Sugar	*Clostridium botulinum*, *Listeria monocytogenes*	Pesticides and heavy metals: increased residues	Foreign bodies
Starch	Mycotoxins		Foreign bodies
Additives		Excess of allowable limit	

Table 4.17 Risk assessment of raw materials.

Raw material part	Biological risk	Chemical risk	Physical risk
Fatling/head/remnants	Microbiological risks relative to visible problems such as fever and rashes. Non-visible microbiological risks, e.g. *Toxoplasma gondii* Visible parasites, e.g. Taenia saginata (*Cysticercus bovis*)	Chemical remains, e.g. antibiotics, herbicides etc.	Placed metal objects, e.g. broken needles
Intestinal path	Microbiological risks relative to stomach and intestine excrements and contents, e.g. *Salmonella* spp., *E. coli* O157:H7, *Clostridium* spp., *Campylobacter jejuni*		
Skin	Microbiological risks due to skin contamination with excrements, dirt etc. such as *Salmonella* spp., *E. coli* O157:H7, *Clostridium* spp., *Campylobacter jejuni*		
Breast	Microbiological risks due to contamination from breast milk, e.g. *Staphylococcus aureus*		

Table 4.18 Supporting functions of meat.

Process stage	Potentials risks description	Preventive actions	Executed controls	Critical limits	Responsible	Corrective actions	Correct. Actions responsible	Files – forms
Water general control	Pollution or alteration of water quality Water ultra-chlorination	Water chlorination from bore Connection with dosimetric chlorine pump operating with alarm Microbiological control results receipt every 2 months and physicochemical control results receipt annually	Water microbiological and chemical control	Characterisation of water as potable according to the prevailing law (98/83/EE)	Production manager Approved external laboratory	Closure Water rechlorination and counter-check	Production manager	File of laboratory controls
General health conditions in the industry	Product contamination caused by the presence of insects or mice Product contamination due to deficient conditions of hygiene, machines, installations and production personnel Product contamination due to chemical materials used in the production Product contamination caused by infectious diseases of personnel	Application of the EU Directive 93/43, of the Code of Foods and Beverages principles, of GMP general principles. Parallel education of personnel. Application of the work directive (Clearing, Disinfection, Pest control) Health booklets	Continuous control of health conditions, spaces, machines, personnel and pest control programme Weekly inspections of the maintenance of spaces, personnel Swab test, residue control by phenolphthalein indicator once a month Health booklets	According to the EU directive 93/43 requirements and the Code of Foods and Beverages principles Absolute disinfection Negative test for the index Absence of dermic, intestinal and respiratory diseases	Production manager Cleaner Production manager	Immediate revocation of every non-compliance Re-education of personnel Immediate removal from work and full recovery of the employee Repeat of disinfection	Production manager	Cleaning and disinfection file Weekly inspection of spaces, installations and personnel maintenance Cleaning and disinfection execution Personnel file
Compliance with the work directives by personnel	Cross contamination Foreign bodies transport	GMP observance Hardwashing Cleaning of gloves. aprons	Hourly control during the work	Absolute compliance	Production manager	Direct revocation of every non-compliance	Production manager	
Maintenance of temperature desirable conditions	Development of micro-organisms	Periodic control of air-conditioning	Temperature and product control twice per shift	$<12^{\circ}C/<7^{\circ}C$ (cuts) $<12^{\circ}C/<4^{\circ}C$ (mince meat) $<5^{\circ}C/-2^{\circ}C$ (products from frozen)	Production manager	Correction of space temperature Repair of air-conditioning damage	Production manager	Temperature space/product surveillance

Table 4.19 Synoptical templates of HACCP monitoring of various products.

Process stage	Potential risks description	Preventive actions	Executed controls	Critical limits	Responsible	Corrective action	Correct. act. responsible	Files – forms
Meat receipt	Contaminated meat raw materials Raw materials receipt in inappropriate conditions Antibiotics, pesticides residues, heavy metals Foreign bodies	Reliable suppliers/certificates control Temperature control during the receipt and quality control during the receipt: Macroscopic (according to the work directive)	Certificates suitability control Temperature control during the receipt Visual control	Every product not accompanied by certificate of conformance should be rejected T of meat surface $<7^{\circ}C$ or $<-17^{\circ}C$	Quality control manager HACCP coordinator	Return of inappropriate materials Briefing of the supplier	HACCP coordinator	File of receipt
Raw materials receipt	Contaminated raw materials Raw materials receipt in inappropriate conditions Pesticides residue, heavy metals Foreign bodies	Reliable suppliers/certificates control/labelling control Truck temperature control Quality control during the receipt: Macroscopic (according to the work directive). Reliable suppliers	Visual control Truck temperature control Microbiological analysis control every 3 months and chemical analysis control every 6 months	No contamination point $T \leq 6^{\circ}C$ Pesticides and micro-organisms residues according to the law specifications	Quality control manager	Rejection of lot Recommendations, strict surveillance and re-evaluation of suppliers who had problems	Quality control manager	File of certificates from the suppliers File of receipt File of laboratory controls Non Compliance Registration Report, corrective and Preventive Actions
Packing materials receipt	Migration of monomers from inappropriate packaging materials. Contaminated packings	Suppliers evaluation/certificates control every 6 months	Labelling control Packings visual control	All packaging which is non-labelled as well as dirty containers should be discarded	Quality control manager HACCP coordinator	Return of inappropriate materials Supplier's information	HACCP coordinator	Receipt file
Cold storage/ freeze/marination/ freezing of meat	Growth of psychrotrophs due to inappropriate chilling conditions, delay of distribution in the fridge and excessive loading in the fridge.	Freeze inspection and assurance of critical limits observance. Cooling chambers are controlled and their temperature is recorded continuously. Use before the expiration date	Temperature control/confirmation of operation of recording meters every day/data saving	Fridge temperature $0–2^{\circ}C$ Cold storage temperature $-20^{\circ}C$	Quality control manager	Location and withdrawal of cause for exceeding the critical limits Repetitive control on the spot to make sure there is an effective operation. Hold of all products following the last satisfactory control. Bad products rejection	HACCP coordinator	Production file Non Compliance Registration Report, Corrective and Preventive Actions
Transport	Release of inappropriate products Transport under inappropriate conditions	Final product control before every loading Loading after the vehicle freeze	Closure–label elements Final product microbiological control once in a month Vehicle temperature	No open containers According to regulations $0–2^{\circ}C$ $-20^{\circ}C$	Distribution responsible Production responsible Driver	Closure – re-labelling Rejection – revocation of products which may be defective Rejection	HACCP coordinator	Non Compliance Registration Report, corrective and Preventive Actions Temperatures registration file Production file

so this procedure should be modified before application to other meats (e.g. pork, lamb or poultry).

Before beginning beef cattle production, the rearing site (wintering, barn rearing), water supplies and all associated equipment should be assessed with regards to all chemical contaminants under consideration and their suitabilities for all intended use determined (Ropkins *et al.*, 2003).

A number of controls should be considered for cattle born on site: background contamination from the site, site practices and site chemicals. In addition, a significant proportion of the maternal parent's body burden of organic chemical residues can be transferred to the offspring. Therefore, the maternal parent is a potential CCP both at birth and during weaning. Division of the latter stages of rearing into post-weaning calf and adult beef cattle should be carried out because calves and adult beef cattle are likely to be treated differently (e.g. different feeding practices, different degrees of medical attention, different locations). Furthermore, calves are likely to be more susceptible to chemical contaminants.

Additionally, cattle can be moved around significantly during rearing for grazing or medical treatment, or housed in barns during wintering or bad weather.

Controls include field grazing and enclosed rearing. Selection for slaughter is the final stage at which livestock can be assessed.

All subsequent processing, storage and associated activities (i.e. site and equipment maintenance and cleaning) should be carried out according to good working practices, using applied chemicals, materials and site chemicals suitable for their intended purposes. Skinning and evisceration have both previously been identified as potential CCPs for chemical residues.

The microbiological effects on the product of the series of operations for skinning the hindquarters of beef carcasses at three packing plants were assessed by Gill *et al.* (1998). Samples were obtained at each plant from randomly selected carcasses, by swabbing specified sites related to opening cuts, rump skinning or flank skinning operations, randomly selected sites along the lines of the opening cuts, or randomly selected sites on the skinned hindquarters of carcasses. A set of 25 samples of each type was collected at each plant, by taking a single sample from each selected carcass. Aerobic counts, coliforms and *E. coli* were enumerated in each sample, and a log mean value was estimated for each set of 25 counts on the assumption of a log normal distribution of the counts. The data indicated that the hindquarters skinning operations at plant A were hygienically inferior to those at the other two plants, B and C, with the mean numbers of coliforms and *E. coli* being about two orders of magnitude greater, and aerobic counts being an order of a magnitude greater on the skinned hindquarters of carcasses. The data further indicated that the operation for cutting open the skin at plant C was hygienically superior to the corresponding operation at plant B, but that the operations for skinning the rump and flank at plant B were hygienically superior to the equivalent operations at plant C. The findings suggest that objective assessment of the microbiological effects on carcasses of beef carcass dressing processes is required to ensure that HACCP and quality management systems are operated to control the microbiological condition of carcasses. The flow diagram of raw beef production is given in Fig. 4.3.

4.17.1 Microbiological standards

Sumner *et al.* (2005) have used a qualitative tool and a semi-quantitative, spreadsheet tool, 'Risk Ranger', to develop a risk profile of microbial hazards across the supply continuum for the beef, sheep and goat meat industries. This tool is useful for highlighting factors contributing to food safety risk and for ranking the risk of various product/pathogen combinations. This tool is qualitative and was used as a preliminary screen for a wide range of hazard–product pairings while Risk Ranger was employed to rank in order of population health risk pairings for which quantitative data were available and for assessing the effect of hypothetical scenarios.

High acceptable level of *C. perfringens* (dHighT) risk hazard–product pairings identified were meals contaminated with *C. perfringens* provided by caterers which have not implemented HACCP; kebabs cross-contaminated by *Salmonella* present in drip trays or served undercooked; and meals served in the home cross-contaminated with *Salmonella*.

Medium-risk hazard–product pairings identified were ready-to-eat (RTE) meats contaminated with *L. monocytogenes* and which have an extended shelf life; uncooked comminuted fermented meat (UCFM)/salami contaminated with Enterohaemorrhagic *E. coli* (EHEC) and *Salmonella*; undercooked hamburgers contaminated with EHEC; kebabs contaminated by *Salmonella* under normal production or following final 'flash' heating.

Identified 'low'-risk hazard–product pairings included cooked, RTE sausages contaminated with *Salmonella*; UCFM/salami contaminated with *L. monocytogenes*; and well-cooked hamburgers

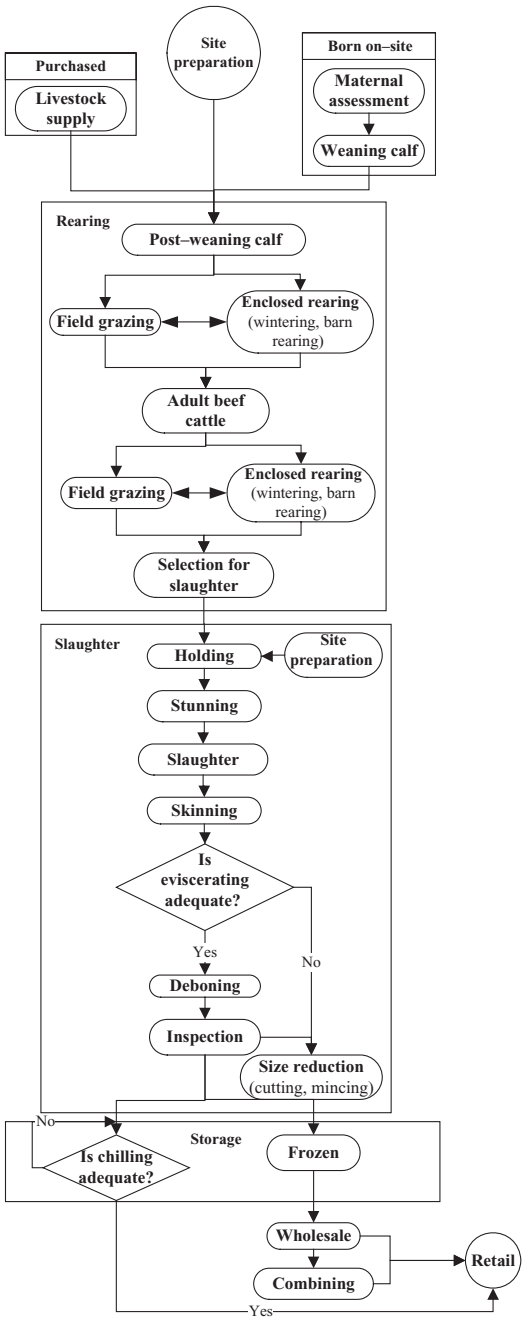

Fig. 4.3 Flow diagram of raw beef production.

contaminated with EHEC. The risk profile provides information of value to risk managers in the regulatory, processing and R and D sectors of the meat and meat-processing industry for the purposes of identifying food safety risks in the industry and for prioritising risk-management actions.

4.18 SAUSAGES

The essential CCPs and general hygiene control points (HCP) from three meat industry processing lines were described by Metaxopoulos *et al.* (2003). The three lines were for (a) the production of cooked sausages (e.g. frankfurter style); (b) the production of cooked–cured meat products (e.g. ham); and (c) the results obtained by evaluating certain microbiological parameters in these points.

On the basis of the audit analysis of many samples (sausages) related to HCP revealed that the application of GHP and HACCP systems was considered adequate but more effort was needed in the control of the microbiological quality of the incoming materials and processing.

In this example, cooked sausages were mainly produced from defatted pork meat and/or mechanically deboned turkey meat (MDM), pork lard, collagen, water, spices, flavour enhancers, and preservatives (e.g. salt, nitrites and ascorbate), soya flour, dried skim milk and starch. All the ingredients were mixed in the cutting machine and then stuffed into casings made mainly of collagen.

Frozen defatted meat and/or MDM was first weighed and then was added with collagen into the cutter machine. Seasonings and ingredients were then added, followed by cooled water or flake ice. With the machine operating frozen pork lard was added and finally the starch. The whole operation was carried out at the appropriate chopping speed and time until an emulsion was produced.

During processing the temperature into the cutter did not exceed 12°C. The emulsion was stuffed in casings of different size. Then the stuffed product was placed in ovens in which they were dried, smoked and finally cooked. The sausages were heated until the core temperature reached 72°C. After thermal processing, sausages were rapidly cooled to a temperature of 35°C using water. The finished product was stored at 0–4°C and packed under vacuum or modified atmosphere in the packaging room prior to its distribution or sale. Frankfurter-style sausages were peeled before packaging (Metaxopoulos *et al.*, 2003). In this process the following points can be identified:

Ensuring the meat core temperature was reached during heat processing is a CCP.

Reducing the temperature from 72 to 10°C had to be achieved within 2 hours. The time needed to cool down the cooked sausages is a second CCP.

In a separate report, the application of high hydrostatic pressure (HHP) (200 MPa) to meat batter just before sausage fermentation and the inoculation of starter culture were studied with a view to improving the safety and quality of traditional Spanish fermented sausages (fuet and chorizo) (Latorre-Moratalla *et al.*, 2007). Higher amounts of biogenic amines were formed in chorizo than in fuet. Without interfering with the ripening performance in terms of acidification, drying and proteolysis, hydrostatic pressure prevented enterobacteria growth but did not affect Gram-positive bacteria significantly. Subsequently, a strong inhibition of diamine (putrescine and cadaverine) accumulation was observed, but that of tyramine was not affected.

The inoculated decarboxylase-negative strains, selected from indigenous bacteria of traditional sausages, were resistant to the HHP treatment, being able to lead the fermentation process, prevent enterococci development and significantly reduce enterobacteria counts. Although starter culture cannot be a reliable measure, it is either the use of a suitable starter or a starter culture per se rather than no starter culture.

Biogenic amines accumulate in food as a consequence of bacterial amino acid–decarboxylase activity. Food produced through a fermentation process is described as particularly rich in biogenic amines. Indeed, the growth of a wide variety of bacteria potentially harbouring decarboxylase activity, the mild acidification and the proteolysis taking place during fermentation are favourable conditions for biogenic amine accumulation.

Fermenting micro-organisms, mainly non-starter lactic acid bacteria (LAB), seem to play a significant role in the amine accumulation, especially tyramine. The contaminant microbial population (such as enterobacteria) also contributes largely to the occurrence of certain amines (such as diamines, putrescine and cadaverine) being indicative of improper hygienic conditions.

Therefore, the optimisation of hygienic conditions of both raw materials and processing is one of the key measures that enable the control of the aminogenesis during food processing and storage (Bover-Cid *et al.*, 2001).

In the case of fermented meat products, high temperatures cause detrimental changes in the raw materials, and thus, it is not possible to apply conventional heat treatments. Alternative non-thermal technologies such as HHP show challenging possibilities in this connection especially in relation to the so-called hurdle technology. HHP inactivates micro-organisms with minimal sensory changes to the product; HHP has promising applications which may satisfy consumer demand for high-quality and safe meat products (Hugas *et al.*, 2002).

Traditional Spanish low-acid ripened sausages are manufactured following traditional procedures, which are based on a spontaneous fermentation process at a relatively low temperature of approximately 10–15°C. The ripening and drying processes ensure low water activity values, but these slightly fermented products are characterised by a relatively high pH (over 5.3). Microflora contamination (Gram-negative bacteria) may not be totally inhibited during the manufacture, compromising the safety and stability of the final product. The inoculation of a competitive and decarboxylase-negative starter culture has been shown to be a useful tool for inhibiting spontaneous aminogenic microflora and thus considerably reducing aminogenesis (Bover-Cid *et al.*, 2000). However, the selection of appropriate strains is essential to retain the typical sensory characteristics of particular artisan-produced products (Di Maria *et al.*, 2002).

The biogenic amine contents, microbial counts and flora producing amines were investigated in four types of fermented sausages by Ansorena *et al.* (2002). Southern type European sausages (Italian and Belgian) showed higher tyramine and phenylethylamine values than Northern type ones (Norwegian and Belgian). The spontaneous non-starter LAB could be responsible for the production of these amines in the Italian products, and the cocci Gram-positive in the south Belgian ones. The Norwegian sausages showed the lowest total amine content of those studied. The two Belgian types were characterised by the highest putrescine contents, associated with high counts of Enterococcus. The production of amines in vitro by the starter cultures used in the manufacture of the sausages revealed that none of the Lactobacillus species produced any amines and only *Kocuria varians* and *Staphylococcus carnosus* showed phenylethylamine and tryptamine production. High correlations were found between the content of putrescine, histamine and cadaverine.

In Austrian dry sausages, highly significant differences were found in the histamine contents of products made by different manufacturers (Tschabrun *et al.*, 1990) and in long ripened products, its concentration reached up to 400 mg/kg dry matter (DM) (Paulsen and Bauer, 1999). Large variations in the amine content and composition were also found in retail Belgian sausages, possibly related to the method of manufacture and the specific flora of the sausages (Vandekerkhove, 1977).

Salmonella Typhimurium DT104 is unwanted in products for human consumption due to its antibiotic resistance and ability to cause disease. Alban *et al.* (2002) intended to set up an improved monitoring and management programme to aid in deciding when to use pork contaminated with DT104 for production of sausages without jeopardising consumer safety. They started by carrying out two assessments of the risk to human health associated with consumption of sausages produced by (1) Danish pork from average slaughter days; (2) imported pork with average prevalence of DT104. The assessments showed that, if *Salmonella* is present, it is usually in low numbers ($\leq$50 per 400 cm^2 surface). Additionally, during processing, the numbers may be reduced by at least 2 log units. In Danish (DK) pork, DT104 constitutes 0.2–1.0% of the *Salmonella* isolates reported, while in imported pork, it is approximately 18%. On this basis it can be calculated that out of 1 million, 25 g servings of DK dry-cured sausages, up to two DT104 bacteria could be found in each of 245 servings. Out of 1 million servings of 25 g IMP dry-cured sausages, up to two DT104 bacteria would occur in each of 19260 servings. Thus, the risk to health is more when imported meat is used – for example in Holland, 0.0245% incidences for Dutch meat compared to 1.926% incidences with imported meat, i.e. a 78.6-fold difference.

Outbreaks of food poisoning due to contaminated sausages have been reported from the USA, where *S. typhimurium* was isolated from semi-dry fermented beef-sausage products. This was probably a result of a very high prevalence in the raw meat or due to processing failures (Sauer *et al.*, 1997). In Italy, *Salmonella* has also been isolated from sausages — primarily in fresh pork sausages, but also in dry–cured (Prencipe *et al.*, 2000). These products had gone through either a natural fermentation or no fermentation at all (fresh sausages). Hence, the reported outbreaks have probably been caused by a high *Salmonella* burden in the raw meat and/or processing failures – perhaps improper acidification and inadequate addition of, e.g., smoke, NO_2 and salt.

Clearly these examples identify two CCPs which all manufacturers should monitor. Regular checks of incoming raw material may reduce the initial problem of the burden of bacteria and appropriate application of HACCP and GHP during processing should reduce the problems arising from processing failures.

The food industry faces many food safety crises, such as BSE (bovine spongiform encephalopathy) or foot-and-mouth disease, and hence it tries both to limit the incurred risk and to reassure consumers. Thus the imperative is not only to trace the products efficiently but also to minimise recalls and to reduce the number of batches constituting a given finished product.

The pork meat industry is particularly interested in improving its traceability (Liddell and Bailey, 2001). As an example a study of a sausage manufacturing process in a French food company is presented. The company tried to minimise the quantity of recalls when products are characterised by a three-level 'disassembling and assembling' bill of material.

Such a 'dispersion problem', encountered in the food industry, has been studied, modelled and solved by Dupuy *et al.* (2005) who proposed a mathematical mixed-integer linear programming (MILP) model. The problem came from a sausage manufacturing process in a French food company. In order to produce sausage, this company cut pork meat into components such as ham, belly, loin and trimmings. Further in the production process, these meat components were minced and mixed to create minced meat batches. These minced meat batches were used to produce different types of sausages. The finished products (sausages) were composed of several components in given proportions.

During a working day, the company receives several batches of different types of raw material (ham, side of pork, shoulder). If a problem arises which is associated with a finished product, the company will identify (track) the raw material batches and then recall all concerned finished products. So, in order to minimise the cost of a food safety crisis, the company has to minimise the number of recalled products. In the case of sausage production, batch size should be reduced, as should batch mixing. The more raw material batches are mixed in finished products batches, the bigger the recall, and the bigger the cost.

The microbial stability of dry sausages is determined by the combination and timing of different factors referred to as the hurdle concept. However, the hurdles present in dry sausage are not sufficient to prevent the survival of *L. monocytogenes* or enterohaemorrhagic *E. coli* O157:H7. Recently bioprotective LAB, in addition to the production of antimicrobial lactic acid, have been found to contribute to the safety of the dry sausage by producing antimicrobial peptides, i.e. bacteriocins and other low-molecular-mass compounds (Tyopponen *et al.*, 2003). Furthermore, the possibility of using probiotics in dry sausage manufacturing processes has been addressed (Muthukumarasamy and Holley, 2007). As one possible mode of action for probiotics is the production of antimicrobial compounds, LAB may act as both probiotic and bioprotective cultures as well as fermenting agents in meat products, such as dry sausage.

Dry sausage material is made from a mixture of frozen pork, beef and pork fat (Tyopponen *et al.*, 2003). In addition, it may contain sugars, salt, nitrite, and nitrate, ascorbates and spices. The raw sausage material is stuffed into casing material of variable diameters and hung vertically in fermentation and ripening chambers for several weeks.

Salt acts as one of the first hurdles against the growth of unwanted micro-organisms. It also induces the solubilisation and diffusion of myofibrillar proteins from muscle forming a gel between meat and meat as well as meat and fat particles of the raw sausage material. Salt (NaCl 2.5–3.0% [w/w], initial value) is also an important flavour component of the end product (Lucke, 1985). Nitrite acts as another hurdle against the growth of pathogens which may be introduced with the raw meat material. It also contributes to the formation of the typical cured meat colour. Ascorbates enhance the colour formation (Puolanne, 1977). Spices, such as pepper, cardamom and garlic, have an impact on flavour and they may also have antioxidative and antimicrobial effects (Hammer, 1977). Furthermore, smoke, consisting of phenols, carbonyls and different organic acids, contributes to the inhibition of different bacteria on the surface of the sausages (Toth and Blaas, 1972).

Sugars are added as fermentable substrates for LAB (inoculation of 6–7 log cfu/g) and staphylococci (6 log cfu/g) used as starter cultures. Catalase produced by staphylococci degrades hydrogen peroxide produced by LAB (Katsaras and Leistner, 1991). In addition, staphylococci reduce nitrate into nitrite (Nurmi, 1966) and have an impact on flavour (Berdague *et al.*, 1993; Stahnke, 1994). Lactic acid bacteria decrease the pH of the sausage close to pH-value 5.0 in the first few days, which acts as a hurdle for several Gram-negative bacterial species (Leistner, 1995). While the pH of the sausage (i.e. salt–meat mixture) decreases and approaches the isoelectric point of the dominant protein species, the water holding capacity of the sausage decreases (Hamm, 1962). This favours the drying and consequently the weight losses of sausage, resulting in the firm texture and sliceability of the end product (Buckenhuskes, 1993).

Alheiras are traditional smoked fermented meat sausages produced in the north of Portugal. In addition to the homemade *alheiras*, more than 500 tonnes are annually produced by various commercial industrial plants (http://www.idrha.min-agricultura.pt/produtos_tradicionais/estatisticas/estatisticas.htm), using pork and other type of meats (duck, turkey, chicken, partridge and calf), representing an important economic resource for the region.

For the production of *alheiras*, the various meats are boiled in water with salt and spices. Bread is thinly sliced and immersed in some of the broth formed during the boiling of the meats and when it is soft enough, meat in small pieces, spices and olive oil and/or fat drippings are added to the mixture. When everything is completely mixed, the paste is stuffed into cattle intestinal casings and submitted to a dry smoke process, usually for no longer than eight days. In previous work, a preliminary chemical and microbiological characterisation of *alheiras* was made. In general, the results obtained have shown that the optimisation of hygiene procedures in the production process improves the quality and safety of *alheiras*. The objective of the study carried out by Ferreira *et al.* (2007) was the characterisation of *alheiras*, traditional Portuguese sausages, with respect to their microbiological safety. Thirty-eight lots from 17 producers were analysed. The microbiological status of the analysed product can be considered of concern in terms of food safety. Although *Campylobacter* spp. and *E. coli* O157 were not detected in any sample, and *C. perfringens* when present was not at levels of concern with reference to public health, *Salmonella* spp. were detected in two lots of industrially produced *alheiras*, and more than 60% of the lots analysed were contaminated with *L. monocytogenes* in concentrations higher than 100 cfu/g.

The utilisation of appropriate starter cultures would improve the acidity at the beginning of the process minimising the proliferation of pathogens. Various LAB having antimicrobial activity against *L. monocytogenes* and other pathogens have already been isolated from various *alheiras*, and the possibility of them being used as starter cultures is being evaluated (Ferreira *et al.*, 2007).

pH and salt levels are insufficient to assure microbiological safety, there is ample opportunity for post-cooking contamination; the products require chill storage and cooking before consumption. Heavy metals and biogenic amines were, in general, within accepted limits for meat products. Lactic acid bacteria comprised the major microflora (ca. 7–8 log cfu/g) with substantial counts of micrococci and enterococci (up to 7 log cfu/g). *E. coli*,*Staphylococcus aureus* and *Listeria* spp. were detected in several samples (Ferreira *et al.*, 2006).

Improving traditional dry sausage safety and standardisation may be achieved by the conjunction of two approaches. First, by the introduction of selective decontaminating procedures targeted towards spoilage and pathogenic bacteria, but preserving technological flora (Ammor *et al.*, 2004); second, by the addition of

starter cultures specially selected from the small-scale facility house flora in order to control the fermentation process and thus to improve product safety and technological quality, while preserving their typicality.

Two different *Enterococcus* strains of non-meat origin, namely *Enterococcus faecium* CCM 4231 and *E. faecium* RZS C13, were used as starter cultures in sausage fermentation by Callewaert *et al.* (2000).

The meat batter used for the preparations of Spanish-style dry fermented sausages contained the following ingredients (g/kg): lean pork, fat pork, sodium chloride, sodium nitrite, potassium nitrate, sodium ascorbate, sodium pyrophosphate, dextrose, lactose, skimmed milk powder, sodium caseinate, Ponceau 4R (Biosystems, Rubi, Barcelona, Spain), black pepper and water. The meat was tempered at –1 to 0°C.

Both strains produce a bacteriocin inactive against other LAB but active against *Listeria* spp. The competitiveness and anti-*Listeria* activity of both strains were monitored during sausage fermentation at both laboratory and pilot scale. The *Enterococcus* strains were partially competitive during meat fermentation and strongly inhibited the growth of *Listeria* spp. The competitiveness of *Lactobacillus amylovorus* DCE 471, also of a non-meat origin, was tested too. This strain is characterised as a strong acidifier and produces a bacteriocin active against other *Lactobacilli*. However, this strain was not competitive in the meat environment. Since no production of off-flavours was detected, the *Enterococci* may be suitable for addition to meat as cocultures to improve food safety.

With short ripened products, if USDA–FSIS (Food Safety and Inspection Service) requirements have to be met, heating is probably the only choice (Incze, 1998). It cannot be excluded of course that multi-target preservation and metabolic exhaustion will help in solving this problem. More extensive research has to be done in order to meet safety requirements. The fashionable field of research on bacteriocins may also contribute offering effective alternatives. With sausages of longer ripening period option 5 (HACCP system including raw batter testing and a 2-log inactivation in fermenting and drying) seems an adequate solution.

Traditional, long ripened and dried sausages and salamis represent a special group of products not only in terms of technology, pH value and richness in flavour and aroma (Nagy *et al.*,1988) but also regarding the low risk as vehicle of EHEC infection. If these products are heavily contaminated during slicing operations, they can cause illness, just as any other food.

The traditional Italian fresh sausage is produced only with the use of pork meat, pork fat, aroma compounds and salt. The meat and the fat are minced together in pieces that can have different dimensions based on the type of sausage to be produced. The different ingredients after mixing are used to fill natural casings from pork or goat. The fresh sausages can be packaged in normal or modified atmosphere.

Staphylococcus spp. are important micro-organisms in meat products. They release lipases that are able to free short-chain fatty acids that are responsible for the aroma of the fermented sausage. The traditional identification methods, which include biochemical tests, are not easy to perform for the separation of micrococci from staphylococci. The variability observed produces a great number of atypical strains. To date these strains have posed a problem as rapid tests have not been available for routine analysis. The biochemical profiles are not always able to identify without doubts some *Staphylococci*; moreover, the use of substrate that are changing colours due to the activity of the micro-organisms introduces a subjective evaluation by the technician (Quere *et al.*, 1997).

The frankfurter-type sausage containing pieces (3–5 mm) of meat, known as pariza, is a highly perishable meat product (pH 6–7 and $a_w > 0.95$). The ability of a commercial culture identified as *Lactobacillus alimentarius* inoculated as protective culture at two different levels, i.e. 1.6×10^3 and 1.6×10^5 cfu/cm of slice, to extend the shelf life of sliced vacuum-packed frankfurter-type sausage, known as pariza, during refrigeration (6–8°C) was investigated by Kotzekidou and Bloukas (1998) in comparison to control samples. The addition of protective culture increased LAB and suppressed other saprophytic micro-organisms like Pseudomonads and *Brochothrix thermosphacta*. Sliced pariza, vacuum packed in pouches with oxygen transmission rate of 3.55×10^{-3} cm^3 m^{-2} 24 h^{-1} Pa^{-1} and inoculated with protective culture, was acceptable up to 51 and 42 days when the level of inoculation was 1.6×10^3 and 1.6×10^5 cfu/cm of slice, respectively, compared to control pariza with a shelf life of 23 days. The influence of *L. alimentarius* on inoculated *S. enteritidis* on freshly produced pariza held under refrigeration (6–8°C) in vacuum packaging in pouches with oxygen transmission rate 3.55×10^{-3} cm^3 m^{-2} 24 h^{-1} Pa^{-1} was also evaluated following their counts during storage. Although slightly lower growth rates of *Salmonella* were observed in samples inoculated with protective culture *L. alimentarius*, multiplication of *S. enteritidis* could not be prevented. The biopreservation system tested here could not guarantee the safety of vacuum-packed sliced pariza when

severe contamination with *Salmonella* occurs in this product.

4.18.1 Cooked sausages

During cutting of all ingredients in the cutter, temperature should remain under 12°C (GHCP2). Internal temperature during cooking is a CCP (CCP1). Sausages are cooked until they reach an internal temperature of 72°C. Following cooking it is a requirement that the temperature is reduced within two hours from 72 to 10°C to avoid the growth of thermotolerant bacteria. The time required to reduce the temperature is CCP2. Water used for cooling could form a contamination source. For this reason the microbiological quality should be checked at least monthly. Basic sources of contamination are the cutters, conveyor belts as well as product handling from personnel during packaging. Moreover, personnel hygiene should be adequate. The flow diagram of production of cooked sausages is given in Fig. 4.4.

Finally, during storage under refrigerated conditions, the temperature should be maintained at 4°C or lower to assure the microbiological safety of cooked products.

The determination of CCPs for cooked sausages and the ISO 22000 analysis worksheet for the determination of PRPs for cooked sausages are summarised in Tables 4.20 and 4.21. The comparative presentation of CCPs according to HACCP and ISO 22000 for cooked sausage is summarised in Table 4.22. The general characteristics of country sausages are summarised in Table 4.23. The flow diagram of country sausages and the flow diagram of boiled sausages are given in Figs. 4.5 and 4.6, respectively.

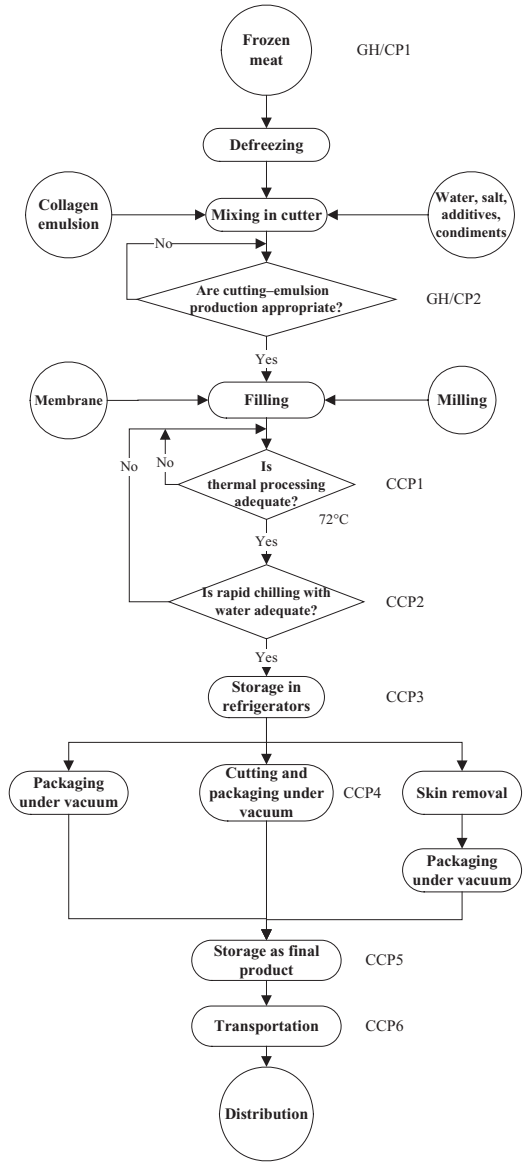

Fig. 4.4 Flow diagram of cooked sausages.

4.18.2 Mechanically separated meat

MRM is the residual meat which has been recovered, using mechanical equipment, from animal bones or poultry carcasses from which the bulk of the meat has been previously manually removed (http://www.food.gov.uk/multimedia/pdfs/mechanicalmeat.pdf).

4.18.3 Biogenic amines in fermented sausages

The toxicological importance of biogenic amines, the low-molecular organic bases formed mainly by decarboxylation of amino acids (Silla-Santos, 1996), is lower in comparison with acknowledged carcinogens such as heterocyclic aromatic amines or *N*-nitroso compounds. However, in allergenic individuals or people being administered monoamine oxidase inhibitors (indirect sympathomimetic drugs) negative health effects after intake of relatively low levels of biogenic amines (e.g. 6 mg of tyramine) can be expected. The flow diagram of production of fermented sausages is given in Fig. 4.7.

Two types of dry fermented sausage differing in spicing mixture and the diameter (low content of red

Table 4.20 Determination of critical control points for cooked sausages.

A/A CCP	Step	Do control measure(s) exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of a hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable levels?	Will a subsequent step eliminate identified hazards or reduce likely occurrence to acceptable levels?	CCP
1	Frozen meat	Yes	No	No	—	cp
2	Thawing	Yes	No	No	—	cp
3	Mixing of ingredients in cutter	Yes	No	No	—	cp
4	Filling	Yes	No	No	—	cp
5	Thermal processing	Yes	Yes	—	—	CCP1
6	Rapid chilling	Yes	Yes	—	—	CCP2
7	Refrigeration	Yes	No	Yes	No	CCP3
8	Cutting/packaging	Yes	No	Yes	No	CCP4
9	Final product storage	Yes	No	Yes	No	CCP5
10	Transportation	Yes	No	Yes	No	CCP6

pepper + diameter 80 mm, H-sausage; high content of red pepper + diameter 55 mm, P-sausage, respectively) were produced in parallel with two different starter cultures (*Pediococcus pentosaceus* + *S. carnosus*, B-samples and *S. carnosus* + *Staphylococcus xylosus* + *Lactobacillus farciminis*, F-samples, respectively) by Komprda *et al.* (2004). The sausages were ripened for 21 days and subsequently stored for 91 days at room temperature. Concentration of both of the most abundant amines, putrescine and tyramine (*y*; mg/kg

Table 4.21 ISO 22000 Analysis worksheet for the determination of prerequisite programmes for cooked sausages.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Frozen meat	Yes	Yes	No	Yes	Yes
Thawing	Yes	Yes	No	Yes	Yes
Mixing of ingredients in cutter	Yes	Yes	No	Yes	Yes
Filling	Yes	Yes	No	Yes	Yes
Thermal processing	Yes	Yes	No	No	No
Rapid chilling	Yes	Yes	No	No	No
Refrigeration	Yes	Yes	No	Yes	Yes
Cutting/packaging	Yes	Yes	No	Yes	Yes
Final product storage	Yes	Yes	No	Yes	Yes
Transportation	Yes	Yes	No	Yes	Yes

Table 4.22 Comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with prerequisite programmes (PRPs) for cooked sausage.

Processing step	HACCP CCPs	ISO 22000 PRP?	ISO 22000 CCPs
Frozen meat	—	Yes	—
Thawing	—	Yes	—
Mixing of ingredients in cutter	—	Yes	—
Filling	—	Yes	—
Thermal processing	CCP1	No	CCP1
Rapid chilling	CCP2	No	CCP2
Refrigeration	CCP3	Yes	—
Cutting/packaging	CCP4	Yes	—
Final product storage	CCP5	Yes	—
Transportation	CCP6	Yes	—

DM) increased significantly ($p < 0.01$) in HB-sausage during ripening and also during storage. At the end of ripening, putrescine (247 mg/kg DM) and tyramine (123 mg/kg DM) content in the HB-sausage was higher ($p < 0.05$) than in the PB-sausage (12 and 9 mg/kg DM, respectively), concentration of either of these amines was negligible (1 mg/kg DM) in either type of F-inoculated sausage. Both starter culture and sausage type influenced significantly ($p < 0.001$) both putrescine and tyramine content in the sausage; starter accounted for 57 and 55% of total variability in putrescine and tyramine content, respectively. Due to the significant ($p < 0.05$) increase of total aerobic counts in the HB-sausage between the end of ripening and the seventh day of storage, followed by the significant ($p < 0.01$) increase of the sum of total biogenic amines between the end of ripening (425 mg/kg DM) and the end of storage (1029 mg/kg DM), the storage of the dry fermented sausages at room temperature should not be recommended.

Table 4.23 General characteristics of country sausages.

Products	Country sausages
General lineaments	Under thermal process: Content in seasonings and content in fat 35% max.
Packing	Packaged in edible cases
Use	Sale in traders consumption after thermal process
Shelf life	Max. 3 months
Storage and transportation instructions	Under freezing 0–2°C
General specifications	(1) Products in compliance with 93/43/EEC and the Code of Food and Beverage (2) Internal regulations of the company

Evaluation of shelf life was made of a type of cooked pork sausage called 'piroski', stored in vacuum and in six different modified atmospheres at 4 and 10°C by Pexara *et al.* (2002).

Presence of visually identifiable foreign materials (e.g. faeces or ingesta) on red meat animal carcasses or carcass-derived tissue surfaces is an indication of poor process sanitation, which may result in the failure of subsequent decontamination strategies leading to rapid product spoilage and an increased risk to public health depending upon the types and numbers of associated micro-organisms (Bacon, 2005).

Trimming of carcass surfaces by plant employees at animal-to-carcass conversion rates ranging from 100 to 400 head per hour not only resulted in significantly less visually identifiable faecal contamination but also reduced aerobic plate and biotype I *E. coli* counts by 1.3 and 1.6 log cfu/cm^2, respectively. In addition, *Listeria* and *Salmonella* spp. prevalence was reduced from 43.7 and 30.3 to 25 and 7.7%, respectively. Trimming of contaminated surfaces reduced *E. coli* O157:H7, *S. typhimurium* and *L. monocytogenes* counts by 3.1, 2.7 and 2.5 log cfu/cm^2, respectively (Phebus *et al.*, 1997). Similarly, Castillo and his coworkers (1998) determined the antibacterial efficacy of various decontamination treatments applied to beef round, brisket and clod surfaces following artificial contamination with inoculated and non-inoculated faeces.

Total viable count (TVC), LAB, pH changes, colour attributes and the presence of pathogenic bacteria (listeriae, staphylococci) were monitored during the storage. Pexara *et al.* (2002) showed that the average shelf life for both products was two and one week at 4 and 10°C, respectively. By the end of these periods, the bacterial population consisting of only LAB reached 10^8 cfu/g. Macroscopical (colour, drip loss and slime) and organoleptical changes (sour odours) were not related to pH and observed already at pH values >5.5. They concluded that the use of modified atmosphere packaging in these tests did not extend and not reduce the product shelf life in comparison to vacuum packaging.

Risk assessment is also an important approach for food companies: (i) during product development, (ii) during hygienic process optimisation and (iii) as an

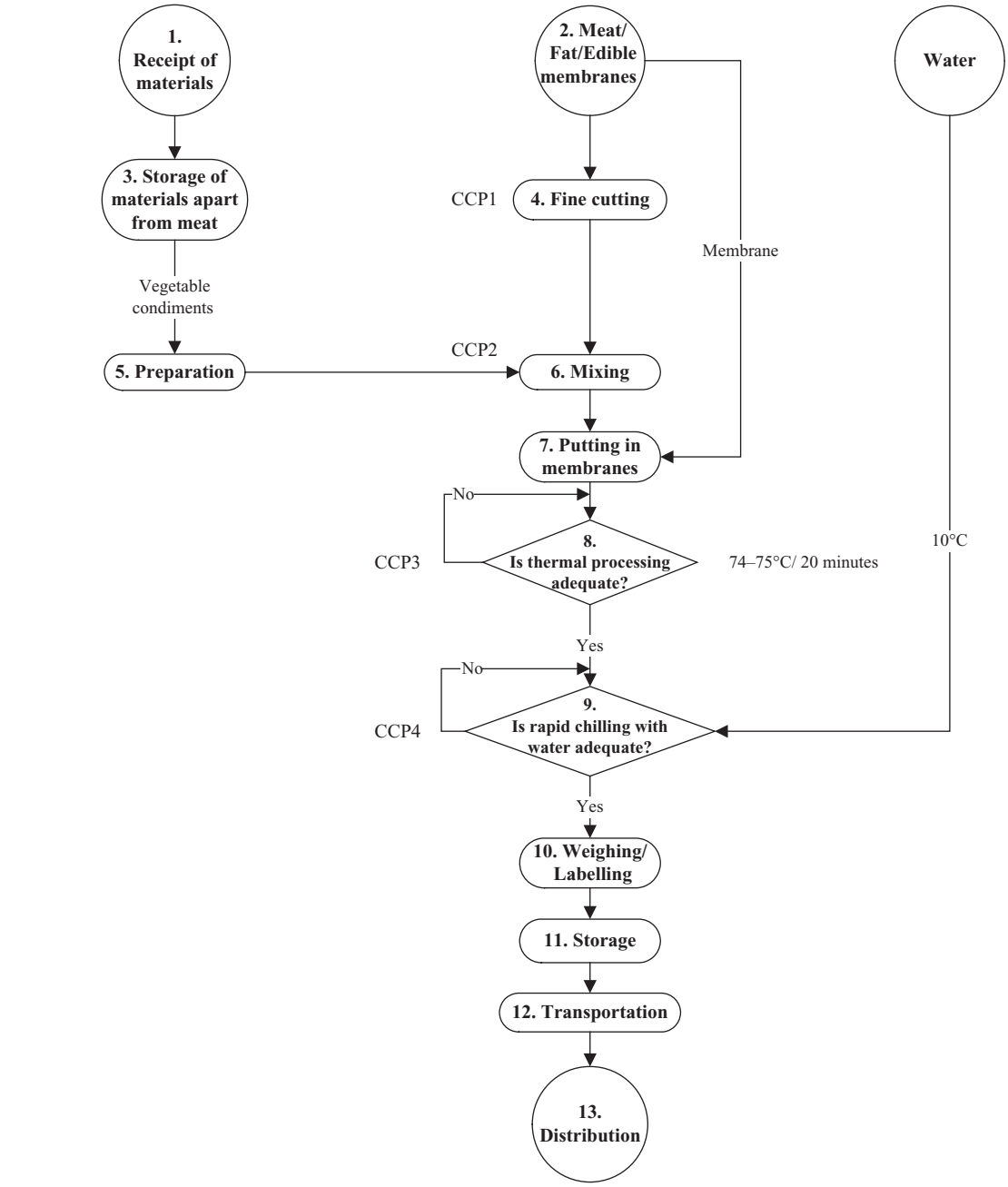

Fig. 4.5 Flow diagram of country sausages.

extension validation of the more qualitative HACCP plan.

The objective of the risk assessment by Hoornstra and Notermans (2001) was to see if a criterion should be set for the reduction of *E. coli* O157:H7 during the production of raw fermented sausages. QRA integrating data from the literature, challenge tests, other microbiological information and assumptions, combined

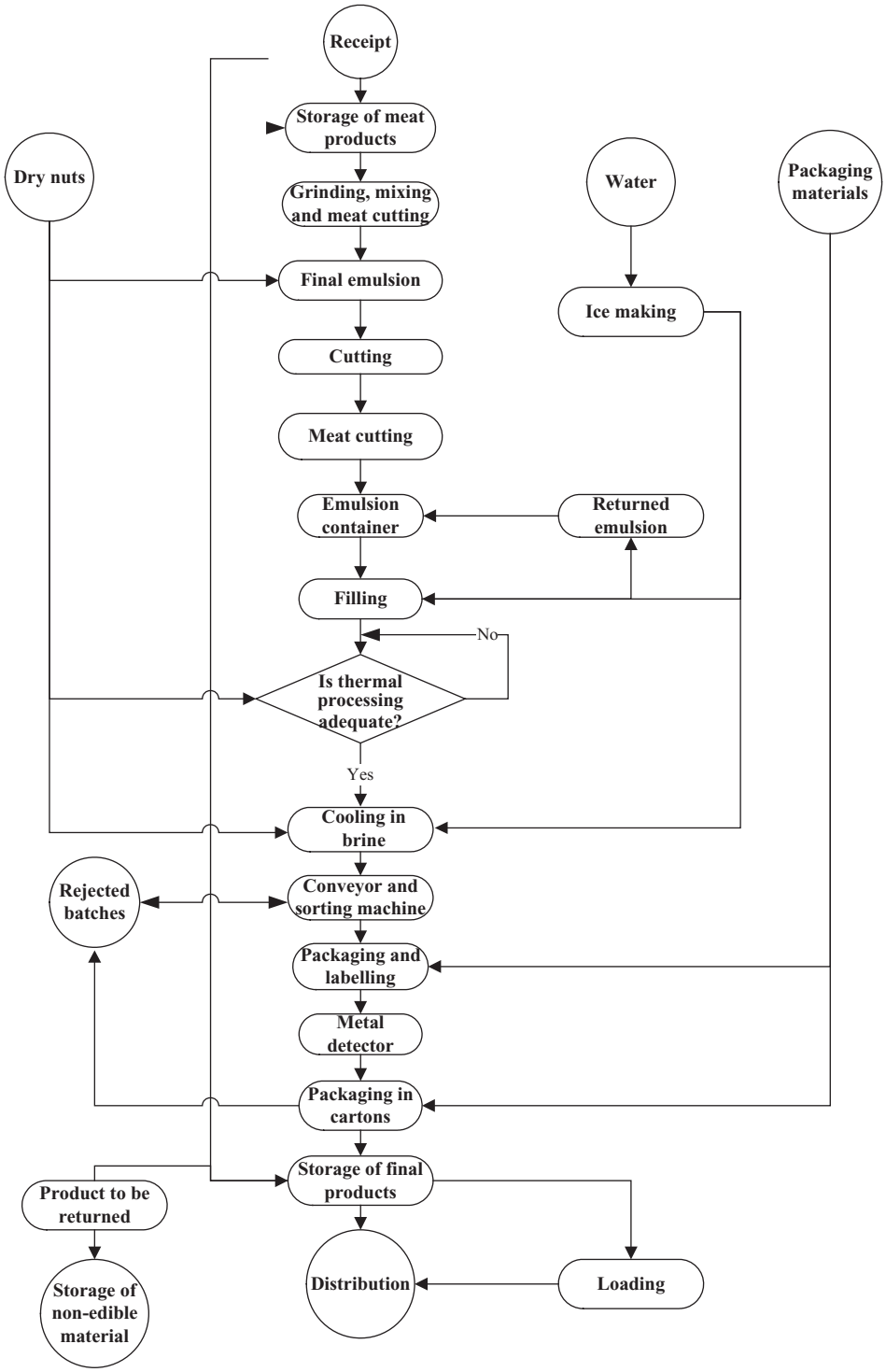

Fig. 4.6 Flow diagram of boiled sausages production and distribution.

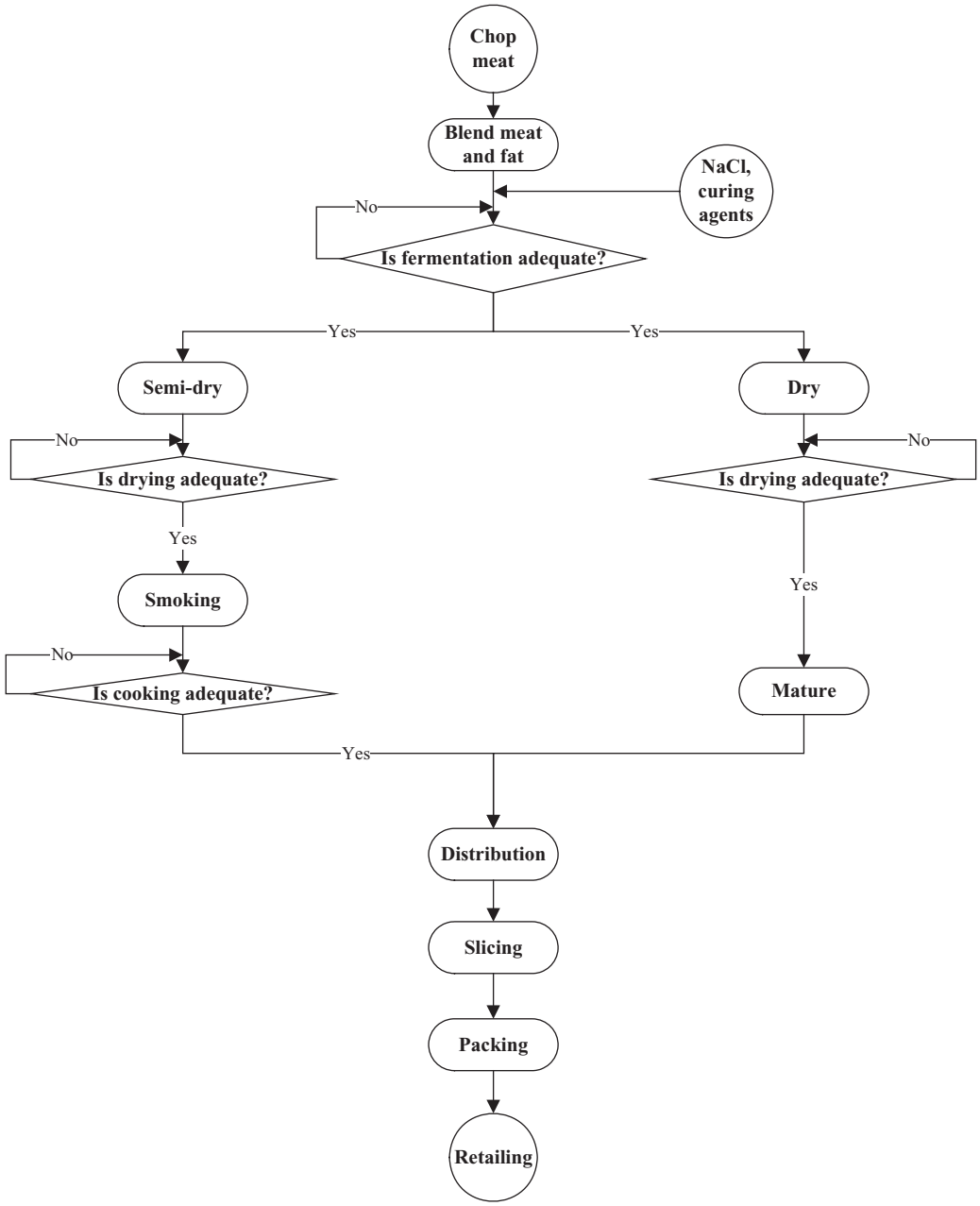

Fig. 4.7 Production of fermented sausages.

with the use of applied statistics, was used to complete a risk assessment for two different types of sausages.

The process began with identification of the risk-contributing factors in the food chain, followed by quantification of the impact of each risk factor using probability distribution functions. Statistical calculations were made including the distribution of the pathogen on the beef meat, the amount of beef meat in the raw material mix and the distribution of the pathogen during portioning into sausages.

The probability of detecting *E. coli* O157:H7 in a 25-g sample of sausages processed under the original procedures was 0.15%. The probability of such detection in sausages subjected to the longer and more controlled heating process was 0.09% and the probability of such detection in sausages subjected to the higher temperature treatment was 0.04%. Provision of this type of information allows the risk manager to decide whether to change the process, depending on the levels of safety required. Such information also allows the accurate prediction of the likely impact of other measures that could be taken to improve levels of safety, such as selection of better quality raw materials or additional decontamination process and new preservation techniques. The ability of the risk assessment approach to provide such information clearly indicates that it goes beyond the more qualitative HACCP approach, and is an essential tool in the management of food safety problems and in cost-effective and efficient product and process development (Hoornstra and Notermans, 2001).

'Salsiccia', a type of fresh Italian sausage, is one of the most popular and widespread meat products in Italy. According to Italian legislation, 'Salsiccia' is obtained from chopped meat stuffed in small casings, added with nitrates and nitrites up to 250 and 150 ppm, respectively, to prevent meat browning and inhibit *C. botulinum* growth (Cammack *et al.*, 1999). Moreover, in combination with ascorbic acid, others additives such as lactose and glucose, are added in order to activate a slight fermentation.

This type of traditional food, which generally is stored under refrigerated conditions (2–4°C) and consumed after cooking, does not undergo an intense sugar fermentation nor drying and presents a shelf life ranging between 8 and 10 days. Although it is based on a simple mixture of pork meat, pig fat, salt, pepper and sometimes garlic, consolidated regional traditions have given rise to several variants in terms of ingredients, texture and flavour. Particularly, 'Salsiccia Toscana' is one of the most appreciated traditional sausages produced in Italy.

Kamdem *et al.* (2007) tried to evaluate the efficacy, in terms of safety, shelf-life extension and keeping quality of different commercial ingredients, including nitrite/nitrate and spices, of fresh Italian Toscana traditional sausages. In particular, the role of spices, in the possible reduction or replacement of nitrate and nitrite, was investigated. The data evidenced the significant role of the spices on the growth reduction of deliberately inoculated *L. monocytogenes*. The principal component analyses of the microbial metabolite and sausage flavours suggested that the microbial activity was affected more by spices than by nitrite and nitrate extent.

One hundred and fifty four dry fermented sausage small- and medium-sized enterprises (SMEs) were visited by Conter *et al.* (2007) in northern Italy, to collect information on building and facilities, production technology and marketing organisation. Five businesses, out of 154, were then selected with the aim of analysing their PRPs and the level of HACCP system implementation. The results of this survey acknowledge the importance of small enterprises in the dry fermented sausage production sector. They showed that full compliance with PRPs and HACCP is far from complete, especially in micro-sized businesses, in spite of derogations for small establishments provided by Italian and European rules. In order to help SMEs to comply with food safety objectives (FSO), collaboration with local health unit officers always proves positive for the businesses because they can inform and support enterprises, particularly small food premises. Before implementing a HACCP system, a food business should already have in place various practices that may be collectively termed 'prerequisite programmes' (PRPs) (e.g. raw materials specifications, staff training, hygienically designed facilities and good hygienic practices [GHP]).

The majority of food businesses recognised the importance of the sanitisation programme, and had a good knowledge of cleaning and disinfection procedures. Cleaning took place with the same procedure everywhere: Firstly, removal of macroscopic residues followed by successive treatments with water, detergent, water, disinfectant, and water.

The main deficiencies regarded the presence of lines crossing in the lay out, the absence of pest control plans, the insufficient frequency of clothes changing, the presence of a relatively high temperature in the meat reception area and, finally, the absence in one workshop of a control plan for sample analysis. The corrective actions are:

1. All areas should be well separated and personnel are expected to follow a certain path without being obliged to cross other departments which could potentially result in cross-contamination.
2. A pest control plan should be in place and the monthly results must be able to confirm its effectiveness.
3. Training the personnel is essential regarding GHP and records should be kept.
4. Thermometers are expected to be in various areas (production, storage) and preferably connected

with an alarm system in case the temperature exceeds the upper acceptable limit.
5. A control plan for sample analysis should be in place and available to workers involved.
6. (Schmidt and Newslow, 2006).

Raw, newly produced sausages containing a mixed starter culture of lactobacilli and micrococci were each inoculated at separate locations by Nissen and Holck (1998) (using a syringe) with low (10^3–10^4 cfu) and high (10^5–10^7 cfu) numbers of either *E. coli* O157:H7, *L. monocytogenes* or *Salmonella kentucky*. Three identically prepared sausages were analysed at each sampling day during fermentation, maturation and storage at 4 and 20°C. In the low-inoculum samples, growth was observed initially (2 days) during fermentation for *E. coli* O157:H7 (3 $\log_{10}$ increase in cfu) and *L. monocytogenes* (fivefold increase in cfu) but not for *S. kentucky* which decreased below the detection limit (150 cfu per sample). None of the pathogens was detected after 5.5 months, neither at 4 nor 20°C. In the high-inoculum samples there was a decrease during fermentation and maturation for all the pathogens. After 5.5 months storage at 4°C, there was only about a 90% reduction of the original inoculate of *L. monocytogenes*, whereas *E. coli* O157:H7 survived at a low number (500 cfu per sample) and *S. kentucky* disappeared below the detection limit. After 5.5 months storage at 20°C, all the pathogens had disappeared below the detection limit. These results indicated that, from a safety point of view, it may be better to store these kinds of sausages at room temperature than in the cold, provided that the sensory qualities are retained and that similar results are obtained with other food pathogens.

The effect of nitrite and starter culture on the survival of Enterobacteriaceae, Micrococcaceae, LAB and other micro-organisms was evaluated by Gonzalez and Diez (2002) during ripening of 'chorizo', a Spanish dry sausage. Sodium nitrite 50 and 150 ppm and *Lactobacillus sake* CL35 added to the 'chorizo' have a significant inhibitory effect on Enterobacteriaceae counts but did not on Micrococcaceae. The use of *Lact. sake* could be an adequate safety factor in this product.

Spices and herbs are generally used in foodstuffs for enhancing the flavour or colour attributes. Moreover, these materials have antimicrobial and antioxidant activity. The most common synthetic antioxidants used in the food industry are butylatedhydroxytoluene (BHT), butylatedhydroxyanisole and *tert*-butylhydroquinone. However, these synthetic antioxidants are banned in several countries due to their carcinogenic risk. Effects of natural (green tea extract, Thymbra spicata oil) and synthetic antioxidants (buthylatedhydroxytoluene) on the safety (biogenic amine and TBARS values) and quality (pH, colour and sensory attributes) of sucuk (Turkish dry fermented sausage) were investigated by Bozkurt (2006) during the ripening periods. Addition of antioxidants decreased ($p < 0.05$) the TBARS values. It was found that natural antioxidants decreased TBARS formation more than buthylatedhydroxytoluene. Antioxidants reduced ($p < 0.05$) putrescine formation in the following order: green tea extract > green tea extract–*T. spicata* oil > *T. spicata* oil > BHT, and their mean values were 70.45, 76.05, 83.13 and 95.97 mg/kg, respectively. The highest tyramine concentration was observed in control sucuk prepared without any antioxidants, while the lowest was in the recipe with green tea extract as their mean values were about 99.42 and 64.31 mg/kg, respectively. The pH, L, b and overall sensory quality were not significantly different ($p > 0.05$) with the addition of green tea extract, *T. spicata* oil, green tea extract–*T. spicata* oil. These results indicated that the most effective antioxidant was found to be green tea extract. This study pointed out that natural antioxidants were more effective than synthetic antioxidants, so they could be easily utilised in sucuk to enhance quality and provide safer products.

Although in the manufacture of fermented sausage any type of meat can be used, meat coming from old animals and of rather low-fat content is usually preferred. Fat is usually added as a separate ingredient and comprises up to 50% of the final product. Pork back fat is widely used, because it has a low content of saturated fatty acids and high melting point. Fat oxidation must be avoided, even by adding antioxidants when it is permitted (Hill, 1995), otherwise it causes rancidity affecting the colour, the flavour, the shelf life and the commercial value of the product (Brody, 1989).

The temperature of the fermentation varies according to the type of sausage. Dry sausage is fermented at 15–27°C for 24–72 hours and semi-dry sliceable sausage at 30–37°C for 14–72 hours. The relative humidity of the chamber should be 5–10% lower than in the interior of the sausage. Sufficient control of temperature and relative humidity can be achieved in enclosed fermentation chambers, without taking special precautions against spoilage during fermentation (Varnam and Sutherland, 1995).

Fermented sausage is generally considered to be a low-risk product, although growth of *S. aureus* and survival of pathogens can occur. Inhibition of *S. aureus* is achieved at a pH value of below 5.3. Thus, the relationship between time and temperature for the drop in pH value down to 5.3 should be considered,

because *S. aureus* can grow before the limiting pH value is reached (Genigiorgis, 1976).

Although the absence of pathogens in fermented sausage cannot be guaranteed because it is a raw meat product, bactericidal treatments including hot water treatment (Barkatte *et al.*, 1993) or spraying with lactic acid (Epling *et al.*, 1993) can eliminate the majority of survived organisms. *Salmonella* can only survive, but hardly grows, in fermented sausage because the infection dose is usually low.

The use of starter cultures is critical to the successful process of sausage fermentation. Cultures usually consist of LAB, *Micrococcus*, *Staphylococcus* and *Debaryomyces* (Daeschel, 1993). The selected strains must fulfil a certain number of criteria, with special emphasis on the competitive exclusion of pathogens and other undesirable micro-organisms, the production of lactic acid, the nitrate reduction, and the improvement of colour and flavour. If insufficient drop in pH value has occurred, there is no point in extending the length of fermentation. Personnel should be well trained and good hygienic conditions should be maintained (Varnam and Sutherland, 1995). Staff:

- completes required training within specified time frame;
- becomes and stays knowledgeable in procedures and methods. Performed, employees are responsible for self-training, through reading current literature, technical papers, publishing technical papers;
- reports all training received and submits documentation for training received; and
- reads and complies with standards, regulations, policies, procedures and work instructions
(FDA, 2005).

4.18.4 Processing stages

4.18.4.1 Casing selection and storage

- All casings should be from an approved source such as those listed in the CFIA reference listing (http://www.inspection.gc.ca/).
- To prevent growth of bacteria during storage, natural casings should be salted or kept in brine (salt and water) at 4°C or lower (but not frozen) in covered containers.
- To avoid mould growth after opening, collagen and fibrous casings should not be kept in warm humid areas but rather in sealed bags or containers in a dry cooler.
- Observe the shelf-life recommendations of the manufacturer for the specific storage method utilised (Good Retail Practices Meat Manual, www.goodretailpractices.net).

Application of the HACCP principles to these points would show the company what CCPs are present and what actions are needed by personnel all of which can then be documented.

4.18.4.2 Meat ingredient selection and storage

- Meat ingredients should be stored covered at 4°C or lower and, if store generated materials are used, ensure they are labelled with the production date.
- Source meat products from establishments which have a HACCP or other type of food safety assurance system.

4.18.4.3 Spice and seasoning selection and storage

- Spices and seasonings should be from an approved source where the manufacturer has in place specific controls to reduce bacteria and ensure they are free of foreign matter.
- Spices and seasonings should be stored covered and be protected from humidity, pests and cleaning chemicals. Whenever possible, place smaller quantities in spice and seasoning bins to avoid opened product from being unused for long periods where bacteria levels or other contaminants may increase.
- Scoops should be cleaned each day, and a separate scoop for each different spice and seasoning is recommended during production.

4.18.4.4 Ingredient inspection and preparation

Inspect natural casings, these should be relatively free of patches of spongy tissue on their lining which can indicate incomplete cleaning during casing production and cause shortened shelf life.

If ice is used in sausage production, ensure that the icebox is cleaned regularly and that only clean scoops (and never hands) are used to remove it. Periodic microbiological testing of ice and water should be performed at least semi-annually.

- If meat ingredients are frozen prior to usage, they should be thawed at 4°C or lower. Inspect meat for off odour, bone chips, cartilage, glands, foreign materials, or any other condition which would make it unsatisfactory for use.
- Select all ingredients in accordance with a first in–first out inventory system and whenever possible avoid the use of rework. When possible, use whole muscle cuts for grinding to enhance shelf life (Good Retail Practices Meat Manual, www.goodretailpractices.net).

4.18.4.5 Sausage production

- During sausage production, quality and shelf life will be greatly enhanced if the meat block is sufficiently cold to ensure that the finished product leaving the stuffer is at 4°C or less.
- Sausage production areas should be kept at no more than 10°C and whenever possible 4°C or colder.
- When moisture addition is required, use ice or cold (not warm) potable liquids and dispense using cleaned and sanitised containers.
- If room air temperatures are 10°C or more, a complete cleanup should be performed at mid-shift to prevent accumulation of bacteria on meat contact surfaces.
- Following stuffing, finished product should be packaged onto clean trays and placed in a refrigerated display case or cooler as quickly as possible.

4.18.4.6 Cooked sausage

- When sausage is cooked verify that adequate cooking temperatures are achieved using a regularly calibrated thermometer.
- Cooked sausages should be chilled as quickly as possible and packaged at 4°C or lower to ensure maximum shelf life and food safety.
- It is very important to make certain that cooked product does not contact any equipment, surfaces or personnel who may have been exposed to raw product. Special care must be taken to ensure that individuals who contact objects such as smokehouse door handles do not pass on bacteria from raw meat juices to cooked sausage.

4.18.4.7 Tumbling

Whenever possible, tumble meat at 4°C or colder to enhance food safety, shelf life, sliceability and yield. Clean and sanitise the tumbler between batches which have a different ingredient or species composition, after each production day or more often if required. Inspect the tumbler daily before production for corrosion, damaged or loose components, or any other condition which could lead to contamination of products. Report any problems to your supervisor.

4.18.4.8 Coating

Apply all coatings in a single-use method. Do not roll or dip meat in storage containers holding spices or other coatings as this will lead to cross-contamination. Place only the required amount of coating material on a clean working surface and following completion throw away all unused ingredients.

4.18.4.9 Marinating

Do not reuse marinades. Ensure that a clean, sanitised, acid resistant and covered container is used to hold marinades and meat ingredients, and to display the finished product. As some marinating processes result in heat production, conduct marinating activities at 4°C or colder.

4.18.4.10 Stuffing

Do not reuse any stuffing materials. Prepare stuffing immediately before use with only cleaned and sanitised containers and tools.

4.18.4.11 Mechanical tenderising or injecting

Disassemble, clean and sanitise injecting or tenderising equipment between batches which have a different ingredient or species composition, at the end of the day or more often if required. Inspect needles or blades before production and after each batch to ensure proper function and to verify that no tips have been broken and entered the product.

4.18.4.12 Allergen control

If potential allergens are used in the production of processed products, ensure that they are declared in applicable labelling or ingredient lists in accordance with regulatory requirements. Ensure that all equipment is completely cleaned before other products are made and that allergen-containing products are segregated. Always follow recipes and do not substitute ingredients which would require labelling or ingredient list changes. The list below contains the names of some foods which are known to cause adverse reactions in susceptible individuals. Remember that products or ingredients made from these foods must also be monitored.

Peanuts, tree nuts (almonds, Brazil nuts, cashews, hazelnuts [filberts], macadamia nuts, pecans, pine nuts, pistachios, walnuts), sesame seeds, milk (including lactose), eggs, fish, crustaceans (e.g. crab, crayfish, lobster, shrimp) and shellfish (e.g. clams, mussels, oysters, scallops), soy, cereals containing gluten (e.g. wheat, rye, barley, oats, spelt), sulphites.

4.18.4.13 Restricted ingredients

Phosphate, nitrite or nitrate compounds, or any other restricted ingredient should be kept in secure labelled location, and added to products with a calibrated scale in accordance with regulatory limits (Good Retail Practices Meat Manual, www.goodretailpractices.net).

4.19 SALAMI

Globally, there have been at least three outbreaks of illness from Enterohaemorrhagic *E. coli* (EHEC) in salamis. In the USA in 1994, salami was recalled because of *E. coli* O157:H7 contamination (Tilden *et al.*, 1996). In Australia in 1995, *E. coli* O111 in mettwurst was implicated; there were around 150 illnesses of which more than 20 progressed to HUS and 1 child died (Cameron *et al.*, 1995a,b). In Canada, illness was associated with consumption of Genoa salami contaminated with *E. coli* O157:H7 (Williams *et al.*, 2000).

Raw fermented meat products, i.e. salami and dry-cured meats, are traditional products, the manufacturing processes for which have developed over many centuries. Salamis, in particular, have been implicated in a number of salmonella outbreaks over the years (Cowden *et al.*, 1989; Pontello *et al.*, 1998; Sauer *et al.*, 1997). Although less frequently, raw, dry-cured meat has also caused salmonellosis outbreaks (Gonzales-Hevia *et al.*, 1996).

The biggest microbiological hazard to meat products clearly arises from the potential contamination of the raw meat with pathogens including *Salmonella*. It is well known that raw meat may be contaminated by a wide variety of *Salmonella* serotypes and the incidence of contamination can be extremely high, depending on the meat species being used (D'Aoust, 1989). The microbiological integrity of the raw meat is therefore of utmost importance to the ultimate safety of these products. It is not possible to preclude the possibility of *Salmonella* being present in raw meat but it is possible to ensure that poor-quality meat, with unacceptably high levels of contamination, is not routinely being supplied (Bell and Kyriakides, 2002).

A variety of food products exist in the retail market that are manufactured by the drying and/or fermentation of raw meat without any associated listericidal heat process. Traditional fermented meats include salamis, such as Danish salami, peppered salami and German salami, whilst those products that are made by only a curing and drying process are termed as raw dried or cured meat and include Parma ham, Prosciutto and Bresaola. These products have a good safety record in respect of *L. monocytogenes*, with no outbreaks of listeriosis being reported that implicate such products. It should be noted, however, that outbreaks of salmonellosis have been recorded, implicating salami products (Bell and Kyriakides, 2002), and these serve as a warning of the potential for these product types to become vehicles for vegetative pathogenic bacteria, causing human infection.

L. monocytogenes cannot grow in most salami and raw dried meats, as the water activity is frequently less than 0.92, which is below the minimum for the growth of the organism. The facts that the conditions that develop in these products during their manufacturing process may reduce *Listeria* contamination levels and that the intrinsic conditions in the finished product do not support their growth probably account for the fact that no reported outbreaks of listeriosis have yet been attributed to these types of products (Bell and Kyriakides, 2005).

L. monocytogenes and *E. coli* O111 have been implicated in several outbreaks of foodborne disease linked to products produced in small batches like Hungarian salami. Traditional meat starter cultures, containing a mixture of LAB and staphylococci, are used to maintain safety and sensory properties of Hungarian salami. The salami is made of a meat formulation consisting of pork back fat, sow hindquarter, beef chuck and pork shoulder. Frozen meat is minced and mixed with NaCl, spices, dextrose, milk solids, wine, $NaNO_2$ and $NaNO_3$.

Pidcock *et al.* (2002) investigated whether non-traditional meat starter (NTMS) cultures can be used for improving the safety of Hungarian salami. Salami batter was inoculated with *L. monocytogenes* and *E. coli* and subsequently fermented with NTMS cultures and a commercially available meat starter. A total of 15 NTMS cultures were tested. The salami was monitored for levels of pathogen, LAB and pH. When used in conjunction with the commercial meat starter, nine NTMS cultures reduced the *E. coli* O111 count by more than 2.5 log units, whereas ten of the NTMS cultures reduced *L. monocytogenes* by more than 2.5 log units. The commercial meat starter alone reduced *E. coli* and *L. monocytogenes* by 1.2 and 1.3 log units, respectively. Some NTMS cultures reduced the pathogen count without affecting the pH of the salami batter. All NTMS cultures survived in salami throughout fermentation and maturation. *L. monocytogenes* and EHEC have been isolated from

faeces and carcasses of cattle at the time of slaughter (Chapman *et al.*, 1993; McNamara, 1995). As a consequence, these pathogens may be incorporated into meat products during manufacture. Human listeriosis has been linked to mettwurst (Loncarevic *et al.*, 1997) and other processed meats (Grau, 1996). Outbreaks of severe diarrhoea and HUS have been linked to salami infected by *E. coli* O111 (Shay and Souness, 1995).

Traditional salami is produced by fermentation of a sausage batter containing meat, curing agents, salt and spices. The growth of pathogenic micro-organisms is suppressed throughout the fermentation. This is due to the inhibitory environment created by a combination of low pH and low water activity. Fermented meats, including salami, various types of fermented sausages and snack sticks, have seen a revival in their popularity in recent years (Moore, 2004). The production of such foodstuffs generally lays in traditional techniques, however, both the quality and in particular the safety of such products intrinsically rests with the microbiology of the fermentation processes. Simultaneously, there has been increased concern over the safety of such products following the increased incidence of outbreaks of *Salmonella* and verocytotoxigenic *E. coli* food poisoning related to these products. This update reviewed the prevalence of fermented meat-associated food-poisoning outbreaks ($n = 13$) and the proposed microbiological specifications used to assess the safety of such foodstuffs. Dry fermented sausage ('salami aeros') is an important product of the Greek meat industry with an annual production of about 10,000 tonnes.

The microbiological and physicochemical changes which occurred during the industrial fermentation and ripening of four batches of Greek dry salami manufactured without starter cultures were reported by Samelis *et al.* (1998). Moderated dehydration rates, monitored by slowly decreasing relative humidity from 94 to 90% during fermentation, prevented the production of insufficiently acidified batches by maintaining microbial activity for longer when the natural inoculum was low. The terminal pH values (5.0–5.2) and water contents (27.7–30.3%) of the sausages were narrowly ranged. Fermentation was governed by an active ($>10^8$ cfu/g) lactic flora, consisting of 'wild' strains of *Lact. sake*. Gram-negative bacteria and aerobic spore formers decreased below 10^2 and 10^3 cfu/g, respectively, while yeasts did not significantly increase during ripening and were below 10^5 cfu/g in the ripened product. Sausages were substantially free of sulphite-reducing clostridia and coagulase-positive staphylococci during the whole process. *Listeria* spp. occurred in the fresh sausage mix, but disappeared from all batches at the latest by the end of fermentation. Enterococci exceeded 10^5 cfu/g during the first days and remained at this level during ripening. Novobiocin-resistant staphylococci matching *Staphylococcus saprophyticus* (mainly) and *S. xylosus* dominated Micrococcaceae populations, ranged between 10^5 and 10^6 cfu/g. It is concluded that to keep or improve the traditional 'sensory type' of Greek salamis, suitable strains of *Lact. sake*, *S. xylosus* and possibly nitrate-reducing *S. saprophyticus* should be selected and validated as starter cultures in experimentally inoculated salamis.

The physical, chemical and microbiological hazards are summarised in Table 4.24, the HACCP plan of pepperoni and salami is shown in Table 4.25 and the process and the shelf stable are given in Table 4.26.

4.20 COOKED–CURED MEAT PRODUCTS

For cooked ham boneless pork from the hind leg cut into large muscle pieces was used while for cooked bacon boneless pork from the belly was used. The cure contained nitrite, salt and other components such as ascorbate, phosphate, antioxidants, spices and sugar.

After butchering to remove fat and rinds, unfrozen meat is mechanically pumped with brine. In each incision a quantity of brine is injected under pressure (1.5–2.0 atm) directly into the muscle tissue. During pumping the temperature of the meat is held at 2°C while that of the brine at 1–4°C. After brining the meat is transferred into a tumbling machine under vacuum and low temperature (0–2°C). Then, the meat is 'massaged' for an appropriate time with short periods of rest. After tumbling, meat is stuffed in casings or nets and subjected to heat processing. Heat treatment might include drying and smoking but not cooking. Heat treatment finishes when a core temperature of 70–72°C is reached.

Then, rapid cooling down to a temperature of 35°C is achieved by a period of 15 minutes rinsing in water. The finished product is stored at 0–4°C, after which it is either sold whole, or cut down in two parts or slices in the cutting room or packed under vacuum or in modified atmospheres (Metaxopoulos *et al.*, 2003).

To avoid contamination of thawed meat fresh brine must always be added. Usually old brines contain salt tolerant bacteria and hence are a potential source of contamination. The whole procedure is carried out at low temperature in accordance with good

Table 4.24 Physical, chemical and microbiological hazards of salami.

Process step	Food safety hazard	Reasonably likely to occur?	Basis	If Yes in Column 3, What measures could be applied to prevent, eliminate, or reduce the hazard to an acceptable level?	Critical control point
Receiving – raw meat	**Biological:** Pathogens *Salmonella* and *E. coli* O157:H7 *Listeria monocytogenes*	**Yes**	*Salmonella* and *E. coli* may be present on incoming raw product. Incoming presence of *Listeria monocytogene* may impact process control and growth	Certification from suppliers that product has been sampled for *Salmonella* and *E. coli* O157:H7 meeting FSIS performance standards. Fermentation and drying or use of post processing kill step could effectively control level	**CCP1B**
	Chemical – None **Physical** – Foreign materials such as broken needles	**No**		Plant records show that there has been no incidence of foreign materials in products received into the plant	
Receiving – restricted and unrestricted non-meat food ingredients; starter cultures/casings; packaging materials	**Biological** – None **Chemical** – Not acceptable for intended use	**No**		Letters of guaranty are received from all suppliers of starter cultures, casings, and packaging materials	
	Physical – Foreign materials (metal, glass, wood etc.)	**No**		Plant records demonstrate that foreign material contamination has not occurred during the past several years	
Storage – restricted and unrestricted non-meat food ingredients; starter cultures/casings; packaging materials	**Biological** – None **Chemical** – None **Physical** – None				
Storage (cold – frozen/refrigerated) – raw meat	**Biological** *Salmonella* *E. coli* O157:H7	**Yes**	*Salmonella* and *E. coli* O157:H7 are reasonably likely to grow in this product if temperature is not maintained at or below a level sufficient to preclude their growth	Maintain product temperature at or below a level sufficient to preclude pathogen growth	**CCP2B**

(*Continues*)

Table 4.24 (*Continued*)

Process step	Food safety hazard	Reasonably likely to occur?	Basis	If Yes in Column 3, What measures could be applied to prevent, eliminate, or reduce the hazard to an acceptable level?	Critical control point
	Chemical – None				
	Physical – None				
Tempering frozen meat	**Biological** – Pathogens	**Yes**	Pathogenic micro-organisms present are likely to grow if time/temperature is not maintained at or below a level sufficient to preclude growth	Control of time/temperature during thawing process. No water tempering	
	Chemical – None				
	Physical – Metal contamination	**Yes**	Plant records show that during mechanical processing metal contamination is likely to occur	Visual inspection prior to stuffing and/or metal detectors are installed prior to packaging	**CCP3P**

P: Physical, B: Biologial, C: Chemical.

hygiene practice. Additionally, the time interval between brine injection and tumbling should not exceed 1 hour. Cooking, cooling, slicing and packing are CCPs.

C. perfringens is a foodborne pathogen of particular concern in cooked meat products because it is a spore former, and it is one of the most rapidly growing bacteria, with generation times as short as 7.1 minutes at optimum temperatures. Spores of *C. perfringens* are heat resistant and can survive typical thermal processing of cooked meat products. This ability is a principal contributing factor for the involvement of this pathogen in foodborne illness.

Thus, conventional thermal processes for meat products, especially those of large size such as boneless ham, roast beef, turkey breast and corned beef, can potentially activate spores of *C. perfringens*. The activated spores can then germinate, outgrow and multiply rapidly to infective levels during cooling of cooked products (Juneja *et al.*, 1994). Therefore, rapid rate and extent of cooling after cooking are critical to prevent foodborne illness caused by this pathogen. Growth of *C. perfringens* during cooling of various cured and non-cured meat products, as well as of other food matrices containing meat, has been reviewed extensively by Doyle (2002).

The FSIS of the USDA established time–temperature compliance guidelines for the cooling of RTE meat and poultry products. These guidelines are part of the performance standards for the production of certain meat and poultry products (final rule), which include lethality (heat treatment), stabilisation (cooling) and handling (U.S. Department of Agriculture, 1999). The FSIS proposed that by following these guidelines the allowable growth of *C. perfringens* would be limited to a log10 multiplication. In the case of cured products (i.e. at least 100 ppm ingoing sodium nitrite), the guidelines recommend that product internal temperature is reduced from 54.4 to 26.6°C in less than five hours, and from 26.6 to 7.2°C in the next ten hours (15 hours total cooling time). For non-cured products, the guidelines recommend that product internal temperature is reduced from 54.4 to 26.6°C in less than 1.5 hours, and from 26.6 to 4.4°C in the next five hours (6.5 hours total cooling time). For large products, meat processors find it difficult to meet these guidelines, especially in small processing facilities, where forced air is the only available cooling method (Amezquita *et al.*, 2005).

Table 4.25 HACCP plan process category: not heat treated, shelf stable product example: pepperoni and salami.

CCP and location	Critical limits	Monitoring procedures and frequency	HACCP records	Verification procedures and frequency	Corrective actions
1B receiving – raw meat	Supplier certification that product has been sampled for *Salmonella* must accompany shipment	Receiving personnel will check each shipment for *Salmonella* certification	Receiving log Corrective actions log	Every 2 months QA will request *Salmonella* data results from company for at least two suppliers	Product without certification will not be accepted if a supplier fails to meet performance standards for two-sample set. Supplier will not be used until a full sample set meets performance standards
2B storage (cold– frozen/ refrigerated – raw meat/poultry	Raw product storage areas will not exceed 4.44°C in refrigerated rooms or exceed −1.11°C in freezer rooms	Maintenance personnel will record raw product storage area temperature every 2 hours	Room temperature log Thermometer calibration log Corrective actions log	Maintenance supervisor will verify accuracy of the room temperature log once per shift. QA will check all thermometers used for monitoring and verification for accuracy daily and calibrate to within 2°F accuracy as necessary. QA will observe maintenance taking and recording temperatures weekly	QA will reject or hold product dependent on time and temperature deviation. Product disposition will be determined by effects of deviation. Process authority will be consulted or cooling curves will be used to make a determination. QA will identify the cause of the deviation and prevent reoccurrence by adjusting maintenance schedule and repairing equipment as required
3P combine ingredients/ processing	No metal particles to exceed 1/32 inches. All kick out product will be reworked to meet critical limit	Maintenance personnel will check the metal detector every 2 hours to assure the kick out mechanism is working properly. All kick out product will be visually examined at the end of the shift or product line and results recorded	Metal detection log Corrective actions log	Maintenance supervisor will verify metal detectors are functioning. QA will verify that the metal detectors are functioning as intended by running a seeded sample through the detector prior to start of each shift. QA will observe examination and rework of kick out product once per week. Kick out device will be tested each shift to determine it is functioning as intended	Mechanical separation line supervisor will control and segregate affected product. Maintenance personnel will identify and eliminate the problem with the metal detector. Preventive maintenance programme will be implemented. QA will run seeded sample through metal detector after repair. All potentially contaminated products will be run through metal detector, X- ray, or visually examined prior to further processing. No adulterated product will be shipped.
4B Fermenting	pH >5.3 within 6 hours.	QA technician will test pH of ten sticks from each lot by probe during the fermentation process every 2 hours and at completion.	Fermentation log pH log Corrective actions log	QA supervisor will observe QA technician perform pH test once per shift. QA will check all pH meters used for monitoring and verification for accuracy daily and calibrate for accuracy daily.	QA will segregate and hold all affected product until correct pH is achieved or other appropriate disposition is determined based on the nature of the deviation, time at pH of product and food safety parameters. Starter culture will be checked for appropriate amount used, dispersion, and storage parameters. HACCP plan and process controls will be changed as required. QA will identify the cause of the deviation and prevent reoccurrence

Table 4.26 Process and shelf stable product: pepperoni and salami.

Process category: not heat treated, shelf stable product: pepperoni and salami
1. **Common name?** Pepperoni salami
2. **How is it to be used?** Consumed as purchased (ready to eat)
3. **Type of package?** Bulk packed (e.g. plastic bag, vacuum packed)
4. **Length of shelf life, varies with packaging and at what temperature? Storage temperature:** may last 3 months non-refrigerated and 12 months under refrigeration
5. **Where will it be sold? Wholesale to distributors consumers?** Only intended use?
6. **Labelling instructions?** Keep refrigerated
7. **Is special distribution keep refrigerated control needed?**

Numerous small meat processors in the USA have difficulties complying with the stabilisation performance standards for preventing growth of *C. perfringens* by log10 cycle during cooling of RTE products.

These standards were established by the FSIS of the US Department of Agriculture in 1999. In recent years, several attempts have been made to develop predictive models for growth of *C. perfringens* within the range of cooling temperatures included in the FSIS standards. Those studies mainly focused on microbiological aspects, using hypothesised cooling rates. Conversely, studies dealing with heat transfer models to predict cooling rates in meat products do not address microbial growth. Integration of heat transfer relationships with *C. perfringens* growth relationships during cooling of meat products has been very limited. Therefore, a computer simulation scheme was developed to analyse heat transfer phenomena and temperature-dependent *C. perfringens* growth during cooling of cooked boneless cured ham (Amezquita *et al.*, 2005). The temperature history of ham was predicted using a finite element heat diffusion model. Validation of heat transfer predictions used experimental data collected in commercial meat-processing facilities. For *C. perfringens* growth, a dynamic model was developed using Baranyi's non-autonomous differential equation. The bacterium's growth model was integrated into the computer programme using predicted temperature histories as input values.

For cooling cooked hams from 66.6 to 4.4°C using forced air, the maximum deviation between predicted and experimental core temperature data was 2.54°C. Predicted *C. perfringens* growth curves obtained from dynamic modelling showed good agreement with validated results for three different cooling scenarios. Mean absolute values of relative errors were below 6%, and deviations between predicted and experimental cell counts were within 0.37 $\log_{10}$ cfu/g. This study introduced the combination of engineering modelling and microbiological modelling as a useful quantitative tool for general food safety applications, such as risk assessment and HACCP plans.

Nitrite is a key ingredient of the cure being responsible for producing the characteristic pink colour in cooked–cured meat products, and contributes to the typical flavour associated with cured meats, and prevents the formation of warmed over flavour (WOF) and meat deterioration flavour (Shahidi, 1992) in cooked meats. However, it is added to cured meat products to provide requisite protection (preservative effect) against micro-organisms especially *C. botulinum* (Cassens, 1995).

It has been well established that an addition of only 50 ppm to cooked–cured meat products is sufficient for colour and flavour attributes, and suppressing lipid oxidation without the worry of WOF development, but larger amounts of nitrite are necessary to ensure the microbial stability of products. However, nitrous acid (from hydration of nitrite oxide produced from the reduction of sodium nitrite) may react with amines in muscle foods (including meat products) to form *N*-nitroso compounds especially nitrosamines, which have toxic, mutagenic, neuro- and nephrotoxic, and carcinogenic effects (Rywotycki, 2002).

Jafari and Emam-Djomeh (2007) tried to reduce nitrite content in hot dogs using hurdle technology without sacrificing product safety and quality. In this study, the water activity of the hot dog was adjusted to 0.95 by the addition of humectants. Although the pH at the hot dog was adjusted with Glucono-delta-lactone to 5.4, the product had ($p > 0.05$) the least acceptance on account of the organoleptic changes (sour taste). Moreover, the temperature of 80 ± 1°C for an hour with the aim of achieving an internal temperature of 75°C was applied. Subsequently, the temperature of the hot dog samples reduced to around 5–6°C within 40–45 minutes, and afterwards the sausages were kept at chilled temperature (>3°C but ≤10°C) throughout their shelf life. There was a decrease in total aerobic counts in hurdle treated hot dogs (with 50 ppm nitrite), compared to the control (with 120 ppm nitrite), whereas *C. perfringens* counts and *C. botulinum* detection were the same ($p < 0.05$) in both hurdle treated and control samples. The obtained results clearly showed that both hurdle treated sample and control had the same ($p < 0.05$) overall acceptability and sensory attributes.

A study of the inhibitory effects of propylparaben and of a combination of lactate and acetate against growth of *L. monocytogenes* in inoculated liquid medium, sliced servelat sausage and cooked ham were performed by Blom *et al.* (1997) using rifampicin-resistant *Listeria* strains in inoculation experiments. A consumer acceptance test of products produced with and without the compounds was also performed. Propylparaben was found to be effective in a model liquid non-fat medium, but was without effect in the actual products. This illustrates the potential pitfalls in translating results from studies in liquid media to fat-containing food products. The combined inhibitory and sensory results showed that a mixture of 2.5% lactate and 0.25% acetate (w/w, calculated on the water phase) could be used to increase the margins of safety for sliced and spreadable vacuum-packed RTE cooked meat products stored for 4–6 weeks. In addition, strict control of temperature during production and storage is very important.

Cured ham is prepared in commercial plants, retail trade and individual houses. The production of canned ham includes curing by injecting the ham with brine (salt, nitrate, nitrite, polyphosphate, ascorbate and sugars), cooking in a hermetically sealed container, chilling and further processing. It is vital that raw materials are purchased from approved suppliers to an accurate and up-to-date agreed upon specification. Certification of analysis should accompany the batches of raw materials, thus confirming that the latter have been sampled and comply with specifications for certain criteria. If no experienced auditors are available internally, third party inspectors should be employed for carrying out effective auditing of the suppliers (Mortimore and Wallace, 1995).

Cooking temperature should be at least 70°C, preferably 80°C, in order to ensure the inactivation of pathogenic bacteria and the destruction of psychotropic organisms (*lactobacilli*, *streptococci*). The outgrowth of germinated bacterial spores can be inhibited at storage temperatures below 10°C (Mossel *et al.*, 1995). At regular intervals and prior to the introduction of a new can size, the time/temperature of the process should be verified by placing thermocouples in the centre of the meat. The initial temperature of the ham, the temperature of the hot water or steam, and the processing time should also be measured (ICMSF, 1988).

Packaging should be done by using an oxygen impermeable film either under vacuum or modified atmosphere (20–30% CO_2 and 70–80% N_2) (Church, 1993; Stilles, 1991). The microflora of vacuum packaged and MAP meat mainly consists of LAB and coryneforms (Zeuthen and Mead, 1996). The package should be clearly labelled 'keep refrigerated', include detailed description of the product, and be legibly and accurately coded (NACMCF, 1992). The conditions of holding, slicing and packaging after cooking are critical, to minimise the risk of contamination with pathogens (Tompkin, 1994). Experience indicates that post-process contamination with *Salmonella* can be prevented and *L. monocytogenes* can be minimised (Mossel *et al.*, 1995). The general characteristics of pasteurised cooked meat are given in Table 4.27. The flow diagram of the pasteurised cooked meat and the flow diagram of production of packaged sliced ham from canned ham are given in Fig. 4.8, Fig. 4.9 and Fig. 4.12 respectively. The evaluation templates of the present risks for the critical control points (CCPs) determination for pasteurised cooked meat are

Table 4.27 General characteristics of pasteurised cooked meat.

Products	**Pasteurised cooked meats (frankfurter, beef, mortadelle, ham)**
General properties	Under thermal process and smoking
	RH max. 62% (it depends on protein%), protein >9%, fat <30% (mortadelle up to 34%)
	Content in meat cuts: mortadelle >50% weight, ham >85% weight Content in salt 1.6–2.2%
	Contains nitrites as sodium nitrite <0.015%
	Contains ascorbic acid <0.05%
	Contains phosphoric compounds <0.5% as P_2O_5
Packing	Cases from collagen or/and cellulose
	B packing: vacuum
Use	Sale in traders Consumption without or after thermal process
Shelf life	Max. 3 months
Storage and transportation instructions	Under freezing 0–2°C
General specifications	(1) Products in compliance with the instruction 93/43/EEC and the Code of Food and Beverage (2) Internal regulations of the company

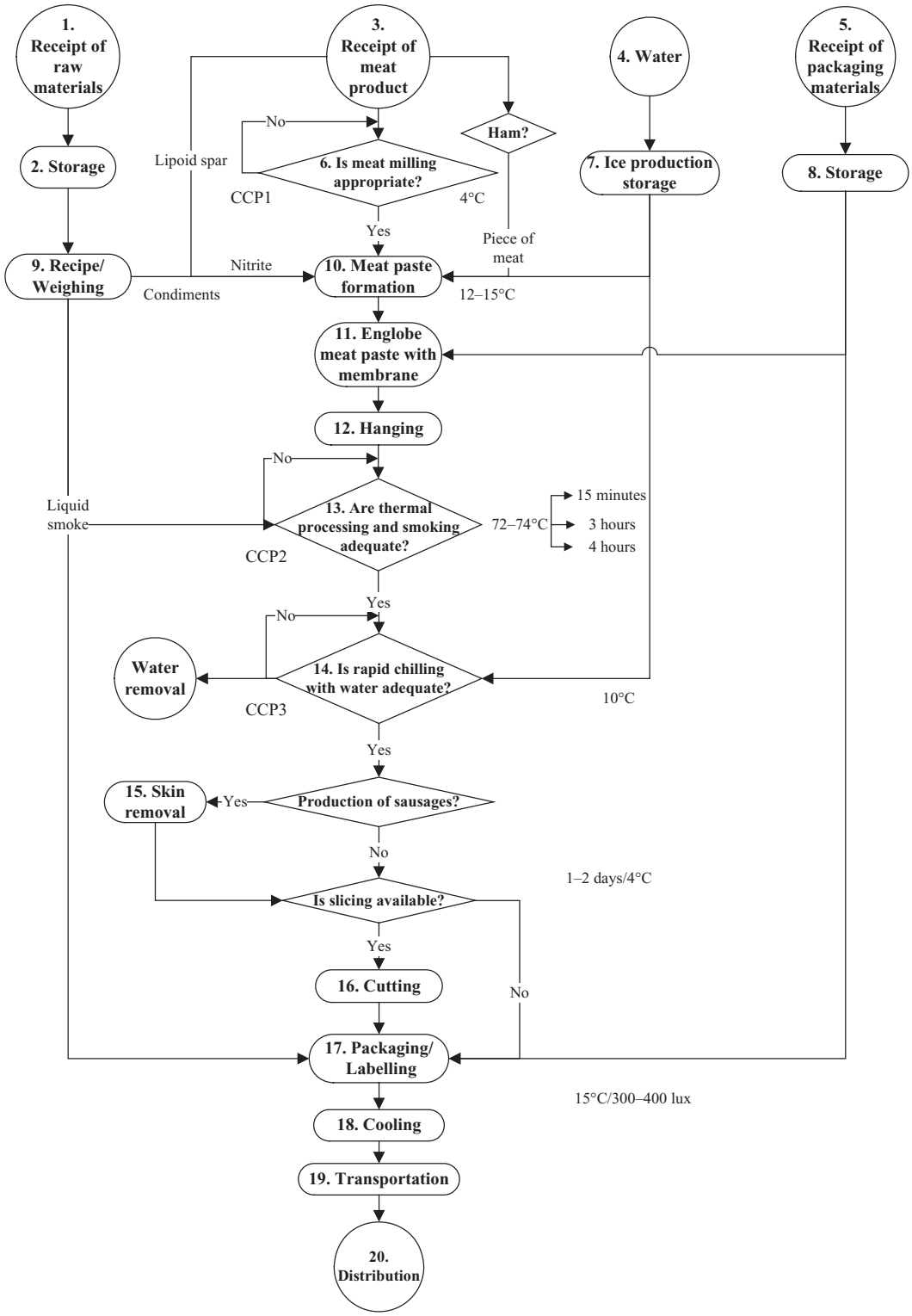

Fig. 4.8 Flow diagram of pasteurised cooked meats production.

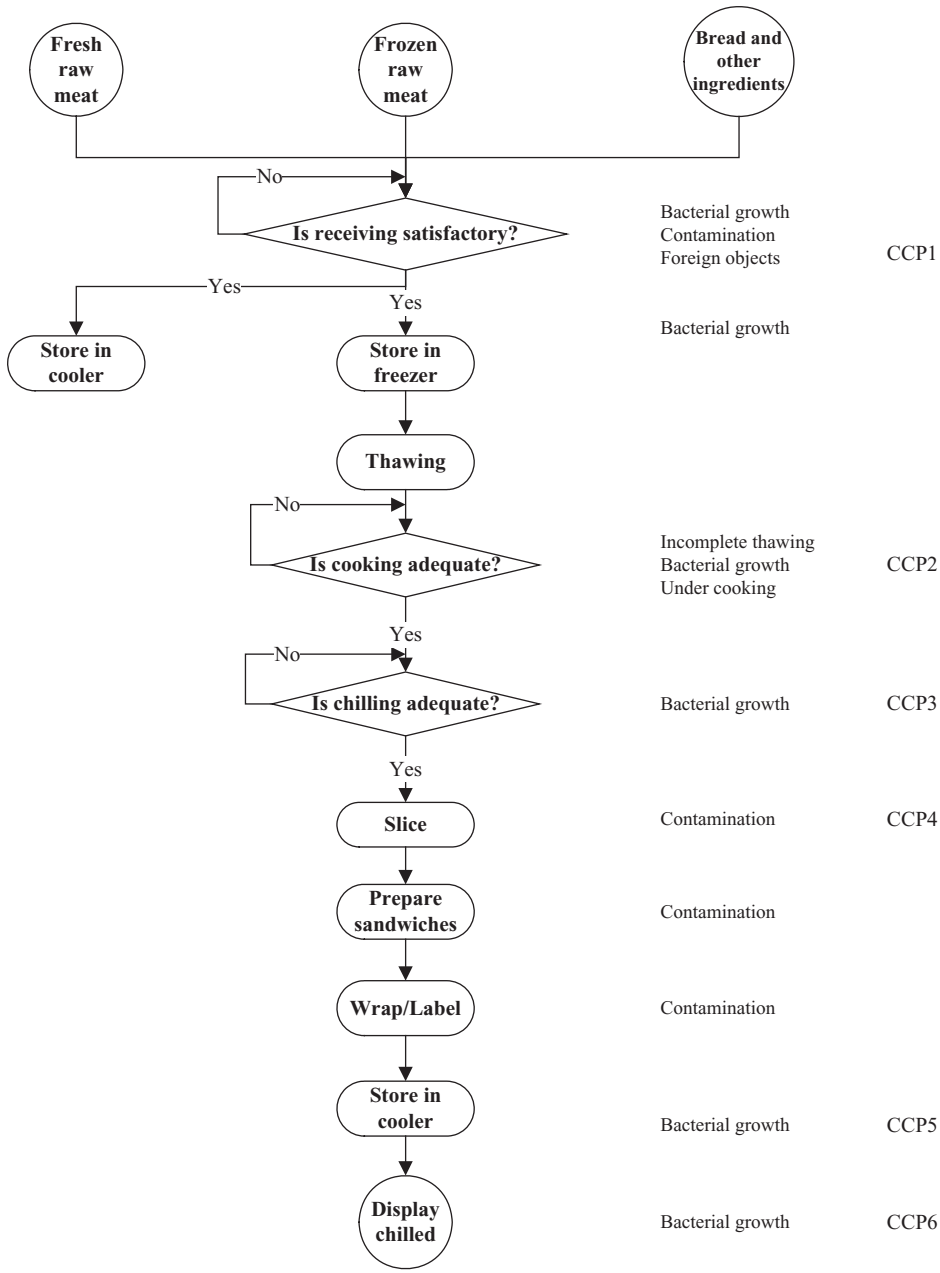

Fig. 4.9 Production of sliced meat sandwich.

summarised in Table 4.28. The ISO 22000 analysis for pasteurised cooked meat is given in Table 4.29. The determination of CCPs according to HACCP and ISO 22000 in conjunction with PRP for bacon meat is summarised in Table 4.30.

Since the traditional dry cure is not well suited to large-scale production, tank cures were developed using concentrated brines. This development permitted the curing of pork on a large scale. The condition of raw meat is important to the quality of the final

Table 4.28 Evaluation templates of the present risks for the critical control points (CCPs) determination for pasteurised cooked meats.

A/A	Process stage	Risk category	Potential hazards description	Q1	Preventive actions	Q2	Q3	Q4	CCP
1	Materials receipt except meat	Biological	Contaminated/expired raw materials	Yes	Reliable suppliers/certificates control/labelling control	No	Yes	Yes	1
		Biological	Raw materials receipt in inappropriate conditions	Yes	Quality control during the receipt:	No	Yes	No	
		Chemical	Pesticides residue, heavy metals		Macroscopic (according to the work directive)				
		Physical	Foreign matters	Yes	Reliable suppliers	No	Yes	No	
2	Materials storage except meat	Biological	Contamination due to deficient hygiene	Yes	Systematic sterilisation	No	Yes	Yes	
		Physical	Foreign bodies transport	Yes	Good practice	No	Yes	No	
3	Meat products receipt	Biological	Contamination due to deficient hygiene	Yes	Systematic sterilisation	No	Yes	Yes	
		Physical	Development of micro-organisms due to high temperatures	Yes	Air-conditioning and temperature control	No	Yes	Yes	
			Foreign bodies transport	Yes	Good practice	No	Yes	Yes	
4	Water	Biological	Water microbial load.	Yes	Water annual full control	No	Yes	Yes	
		Chemical	Residual chlorine load	Yes	Monthly microbiological control of water	No	Yes	No	
5	Packing materials receipt	Chemical	Inappropriate for foods (risk of migration)	Yes	Certificates control	No	Yes	Yes	2
		Physical/ biological	Presence of dust and foreign matter	Yes	Macroscopic control and packing wash	No	Yes	Yes	
6	Meat grinding	Biological	Contamination due to deficient hygiene	Yes	Systematic sterilisation	No	Yes	Yes	
		Physical	Foreign bodies transport	Yes	Good practice	No	Yes	No	
7	Ice production and storage	Biological	Contamination due to deficient hygiene	Yes	Systematic sterilisation	No	Yes	Yes	
		Physical	Foreign bodies transport	Yes	Good practice	No	Yes	No	
8	Packing materials storage	Biological	Contamination due to deficient hygiene	Yes	Systematic sterilisation	No	Yes	Yes	
		Physical	Foreign bodies transport	Yes	Good practice	No	Yes	No	
9	Recipe/weighing	Biological	Contamination due to deficient hygiene/addition of a lower quantity than the required dose of preservatives	Yes	Systematic sterilisation/right estimation of recipe/balance function control	Yes	Yes	No	3
		Chemical	Exceeding of permissible maximum limit of preservative	Yes	Right estimation of recipe/balance function control/preservatives periodic control	Yes			
		Physical	Foreign bodies transport	Yes	Good practice/Materials visual control	No			

(*Continues*)

Table 4.28 (*Continued*)

A/A	Process stage	Risk category	Potential hazards description	Q1	Preventive actions	Q2	Q3	Q4	CCP
10	Meatpaste formation	Biological	Contamination due to deficient hygiene	Yes	Systematic sterilisation	No	Yes	Yes	
		Physical	Foreign bodies transport	Yes	Good practice	No	Yes	No	
11	Storage	Biological	Contamination due to deficient hygiene	Yes	Systematic sterilisation	No	Yes	Yes	
		Physical	Foreign bodies transportation	Yes	Good practice	No	Yes	No	
12	Hanging	Biological	Contamination caused by personnel and equipment	Yes	Systematic sterilisation	No	Yes	Yes	
			Effective thermal process due to wrong placement	Yes	Good practice				
13	Thermal process and smoking	Biological	Micro-organisms survival	Yes	Observance of expected temperatures and times	Yes			4
14	Fast freeze with water	Biological	Inactivation of seeds which survived during the thermal process	Yes	Fast freeze with potable water	Yes			5
15	Decortication	Biological	Contamination caused by personnel and equipment	Yes	Systematic sterilisation of equipment and observance of health conditions by the personnel	No	Yes	No	
		Physical	Foreign materials transport (e.g. hair)	Yes	Good practice	No	Yes	No	
16	Cutting	Biological	Contamination caused by personnel and equipment	Yes	Systematic sterilisation of equipment and observance of health conditions by the personnel	No	Yes	No	
		Physical	Foreign materials transport (e.g. hair)	Yes	Good practice	No	Yes	No	
17	Packing/labelling	Biological	Contamination caused by personnel and equipment	Yes	Systematic sterilisation of equipment and observance of health conditions by the personnel	No	Yes	No	
		Physical	Packing in dirty containers	Yes	Control of containers	No	Yes	No	
			Foreign materials transport	Yes	Good practice	No	Yes	No	
			Non-traceable product		Control label before the release				
18	Freeze	Biological	Development of micro-organisms	Yes	Observance of the temperature expected conditions	Yes			6
		Physical	Contamination caused by polluted storage areas	Yes	Systematic sterilisation Control of expiration date and FIFO observance	No	Yes	No	
19	Dispatch/Distribution	Biological	Contamination caused by unclean trucks	Yes	Systematic sterilisation	No	Yes	No	7
			Development of micro-organisms due to temperature' inappropriate conditions	Yes	Temperature control/packing control	Yes			

Table 4.29 ISO 22000 Analysis worksheet for the determination of prerequisite programmes for pasteurised cooked meat.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Materials receipt except meat	Yes	Yes	No	No	No
Materials storage except meat	Yes	Yes	No	Yes	Yes
Meat products receipt	Yes	Yes	No	Yes	Yes
Water	Yes	Yes	No	Yes	Yes
Packing materials receipt	Yes	Yes	No	No	No
Meat grinding	Yes	Yes	No	Yes	Yes
Ice production and storage	Yes	Yes	No	Yes	Yes
Packing materials storage	Yes	Yes	No	Yes	Yes
Recipe/weighing	Yes	Yes	No	No	No
Meatpaste formation	Yes	Yes	No	Yes	Yes
Storage	Yes	Yes	No	Yes	Yes
Hanging	Yes	Yes	No	Yes	Yes
Thermal process and smoking	Yes	Yes	No	No	No
Fast freeze with water	Yes	Yes	No	No	No
Decortication	Yes	Yes	No	Yes	Yes
Cutting	Yes	Yes	No	Yes	Yes
Packing/labelling	Yes	Yes	No	Yes	Yes
Freeze	Yes	Yes	No	No	No
Dispatch/distribution	Yes	Yes	No	No	No

product (Mackey and Roberts, 1993). Dark, firm, dry meat of high ultimate pH value is undesirable because penetration of curing agents is limited, resulting in an end product that is susceptible to microbial spoilage. Resting and feeding pigs with sugar reduce the incidence of high pH values (Sandrou and Arvanitoyannis, 1999). Good water quality (Mossel *et al.*, 1995) and ingredients and a high standard of equipment hygiene (Troller, 1993) contribute to low numbers of micro-organisms in brines. Filtration, centrifugation and ultraviolet irradiation can be used to reduce the microbial load in recirculated brines since the replacement of brines is expensive and can cause disposal problems.

Immersion in brine lasts for 3–5 days and the temperature should be 4–5°C. Brine is usually a mixture of NaCl and $NaNO_3$ and contains a large population of micro-organisms. The types of bacteria usually found in brines are:

(i) bacteria derived from meat, such as *Salmonella*. *Pseudomonas* is used as an indicator of the quality of pork being cured, while *E. coli* as an indicator of faecal pollution.
(ii) halophilic bacteria of relatively low NaCl tolerance and relatively high biochemical activity. Large numbers of *Vibrio* in brines are predictive of bacon spoilage, while presence of *Vibrio vulnificus* causes severe and often fatal intestinal and extra-intestinal symptoms in susceptible individuals.
(iii) halophilic bacteria capable of growing in high NaCl concentrations, such as *Halomonas*. These bacteria are psychotropic, have low biochemical activity and rate of growth, but they are mainly responsible for reduction of nitrate and nitrite (Varnam and Sutherland, 1995).

The aims of meat immersion in brine are the curing of meat tissues and surfaces, the prevention of bacterial growth, the formation of nitrosylmyoglobin instead of metmyoglobin, and the reduction of nitrate and nitrite. Chemical and microbiological analysis of the brine should be carried out periodically (Mossel *et al.*, 1995), because in many cases filtration is needed for removing particulate matter.

During maturation, it is important to control conditions since extensive microbial growth may occur, resulting in deterioration of quality and stability of the product (Roberts and Jarvis, 1983). At high temperature and humidity, *Janthinobacterium lividum* can produces large quantities of purple slime and *Serratia marcescens* produces pink pigment (Varnam and

Table 4.30 Evaluation templates of the present risks for the critical control points (CCPs) determination for bacon according to ISO 22000.

A/A CCP	Process stage	Kind of risk	Potential risks description	Q1	Preventive actions	Q2	Q3	Q4	CCP
1	Packing receipt	Chemical	Inappropriate for foods (risk of if migration)	Yes	Certificates control	No	Yes	No	1
		Physical/biological	Presence of dust and foreign matters	Yes	Macroscopic control and packing wash	No	Yes	Yes	
2	Packing storage	Biological	Contamination due to deficient hygiene	Yes	Systematic sterilisation	No	Yes	Yes	
		Physical	Foreign bodies transport	Yes	GMP	No	Yes	Yes	
3	Meat receipt	Biological	Contamination due to deficient hygiene	Yes	Systematic sterilisation	No	Yes	Yes	
		Physical	Development of micro-organisms due to high temperatures	Yes	Air-conditioning and temperature control	No	Yes	Yes	
			Foreign bodies transport	Yes	GMP	No	Yes	No	
4	Preparation (cut, rolling etc.)	Biological	Contamination due to deficient hygiene	Yes	Systematic sterilisation	No	Yes	Yes	
		Physical	Foreign bodies transport	Yes	GMP	No	Yes	No	
5	Receipt of materials other than meat	Biological	Contaminated/expired raw materials	Yes	Reliable suppliers/certificates control/labelling control	No	Yes	No	
		Biological	Raw materials collection in inappropriate conditions		Quality control during the receipt:				
		Chemical	Pesticides residue, heavy metals	Yes	Macroscopic (according to the work directive)	No	Yes	No	2
		Physical	Foreign matter	Yes	Reliable suppliers	No	Yes	No	
6	Water	Biological	Microbial load in water	Yes	Water annual full control	No	Yes	No	
		Chemical	Residual chlorine load	Yes	Routine monthly microbiological control of water	No	Yes	No	
7	Storage of materials except meat	Biological	Contamination due to deficient hygiene	Yes	Systematic sterilisation	No	Yes	No	
		Physical	Foreign matter transport	Yes	GMP	No	Yes	No	
8	Recipe/weighing	Biological	Contamination due to deficient hygiene/addition of lower than the required quantity of additives	Yes	Systematic cleaning, proper calculation of recipe, periodic control of preservatives and application of GMP	Yes			3
		Chemical	Exceed of the maximum permissible level of preservatives	Yes		Yes			
		Physical	Foreign bodies transport	Yes		No	Yes	No	
9	Salt water formation	Biological	Contamination caused by the personnel and the equipment	Yes	Systematic sterilisation of equipment and observance of health conditions by the personnel	No	Yes	No	
		Physical	Foreign materials transport	Yes	GMP	No	Yes	No	

10	Infusion	Biological	Salt water smaller quantity	Yes	Meat weighing before and during the infusion	Yes			4
		Chemical	Additives exceeding limit in case of addition of salt water larger quantity	Yes					
		Physical	Fractured needles		Syringe control	No	Yes	No	
11	Massage	Biological	Contamination caused by the equipment	Yes	Systematic sterilisation and equipment maintenance and health conditions observance by the personnel	No	Yes	No	
		Physical	Foreign materials transport	Yes	GMP	No	Yes	No	
12	Formation/hanging	Biological	Contamination caused by the equipment/right placement	Yes	Systematic sterilisation and equipment maintenance and personnel health conditions observance	No	Yes	No	
		Physical	Foreign materials transport	Yes	GMP	No	Yes	No	
13, 16	Freeze	Biological	Development of micro-organisms	Yes	Observance of temperature expected conditions Systematic sterilisation	Yes			5
		Physical	Contamination from polluted storage areas	Yes	Control of expiration date and FIFO observance	No	Yes	No	
14	Thermal process/smoking	Biological	Micro-organisms survival	Yes Yes	Observance of expected temperatures and times	Yes			6
15	Fast freeze with water	Biological	Inactivation of seeds which survived during the thermal process	Yes	Fast freeze with potable water	Yes			7
17	Partition	Biological	Contamination caused by the equipment/right placement	Yes	Systematic sterilisation and equipment maintenance and observance of health conditions by the personnel	NO	Yes	No	
		Physical	Foreign materials transport	Yes	GMP	No	Yes	No	
18	Packing/labelling	Biological	Contamination caused by the personnel and the equipment	Yes	Systematic sterilisation of the equipment and observance of health conditions by the personnel	No	Yes	No	
		Physical	Packing in polluted containers	Yes	Control of containers	No	Yes	No	
			Foreign materials transport	Yes	GMP	No	Yes	No	
			Non-traceable product		Label control before the release				
19	Loading/dispatch	Biological	Contamination caused by unclean trucks	Yes	Systematic sterilisation	No	Yes	No	8
			Development of micro-organisms due to temperature' inappropriate conditions	Yes	Temperature control/packing control	Yes			
			Loading of inappropriate products						

Table 4.31 ISO 22000 Analysis worksheet for the determination of prerequisite programmes for bacon.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute in the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Packing receipt	Yes	Yes	No	No	No
Packing storage	Yes	Yes	No	Yes	Yes
Meat receipt	Yes	Yes	No	Yes	Yes
Preparation (cut, rolling etc.)	Yes	Yes	No	Yes	Yes
Receipt of materials other than meat	Yes	Yes	No	No	No
Water	Yes	Yes	No	Yes	Yes
Storage of materials except meat	Yes	Yes	No	Yes	Yes
Recipe/weighing	Yes	Yes	No	No	No
Salt water formation	Yes	Yes	No	Yes	Yes
Infusion	Yes	Yes	No	No	No
Massage	Yes	Yes	No	Yes	Yes
Formation/hanging	Yes	Yes	No	Yes	Yes
Freeze	Yes	Yes	No	No	No
Thermal process/smoking	Yes	Yes	No	No	No
Fast freeze with water	Yes	Yes	No	No	No
Partition	Yes	Yes	No	Yes	Yes
Packing/labelling	Yes	Yes	No	Yes	Yes
Loading/dispatch	Yes	Yes	No	No	No

Sutherland, 1995). The process of slicing requires attention at the same points as for sliced meat sandwich. Vacuum packaging is an excellent method of maintaining the colour of cured products, especially in oxygen impermeable films (Stilles, 1991).

The main types of organisms are *Micrococcaceae*, *B. thermosphacta*, *Carnobacterium divergens*, *Leuconostoc carnosum*, *Enterobacteriaceae* and yeasts (Hird, 1987). The package should also be legibly coded and properly labelled, providing consumers with sufficient information about the product and its safe use. Another type of bacon is Sweetcure bacon, which has a lower NaCl content and blander flavour than Wiltshire-cured bacon. The evaluation templates of the present risks for the CCP's determination for bacon, the ISO 22000 analysis of production of bacon and the flow diagram of production of tank-cured Wiltshire bacon are given in Tables 4.31 and 4.32 and Figs. 4.10 and 4.11, respectively. A comparison of CCPs of HACCP and ISO 22000 in conjunction with PRP for bacon is given in Table 4.33. The evaluation templates of the present risks for the CCP's determination for country sausages are summarised in Table 4.34.

4.21 MINCED MEAT

In the conversion of beef carcasses to ground beef and retail cuts, microbial contamination is an unavoidable and undesired result. Micro-organisms have been isolated from beef during all the steps of ground beef processing including the outer surfaces of beef carcasses, from boxed beef, from retail cuts and from ground beef. Contamination can occur during processing, by contact with slaughter facility equipment (grinders, belts, saws etc.), by contact with food handlers (hand contact, knives etc.) and by exposure to other environmental sources (air, water) (Jay, 1992). Many different types of pathogenic micro-organisms have been isolated from raw beef most notably *Salmonella* spp. *L. monocytogenes*, *E. coli*, and *Campylobacter jejuni* (Jay, 1992; Kraft, 1992; Silliker, 1980). Commonly,

Table 4.32 Comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with prerequisite programmes (PRPs) for bacon.

Process stage	CCPs (HACCP)	Prerequisite programme (ISO 22000)	CCPs (ISO 22000)
Packing receipt	1	No	1
Packing storage		Yes	
Meat receipt		Yes	
Preparation (cut, rolling etc.)		Yes	
Receipt of materials other than meat	2	No	2
Water		Yes	
Storage of materials except meat		Yes	
Recipe/weighing	3	No	
Salt water formation		Yes	
Infusion	4	No	
Massage		Yes	
Formation/ hanging		Yes	
Freeze	5	No	3
Thermal process/smoking	6	No	
Fast freeze with water	7	No	
Partition		Yes	
Packing/labelling		Yes	
Loading/dispatch	8	No	4

isolated spoilage includes LAB, *Pseudomonas* spp., *Acinetobacter* spp., and *Moraxella* spp. (Kraft, 1992). The evaluation templates of the present risks for the CCP's determination for meat products from minced beef are given in Table 4.35.

4.22 PATÉ

A practical application of the Food MicroModel FMM predictive software is presented by Panisello and Quantick (1998). A case study on meat-based paté is used to illustrate the various requirements needed to assure the safety of this type of foodstuff when pH is reduced. Identification of hazards was obtained from a literature review and confirmed by epidemiological links between the product and foodborne disease outbreaks. For risk assessment four different zones (safe, caution, dangerous and critical) of the level of the variable under study (e.g. pH) were defined, each zone equating to a particular level of risk. Having identified the hazards, associated risks and intrinsic parameters of the paté, a HACCP system can be more readily established using predicted outcomes from FMM.

Predictive modelling is an important component in assessing the changes in product formulation, processing or packaging and can be readily used to evaluate the changes of a wide range of factors upon the growth of the micro-organisms of interest (Baird-Parker, 1994; Notermans *et al.*, 1995).

Predictive microbiology can be used as a system to set the criteria for each CCP, which means to establish target levels and tolerances that must be met to ensure the CCP is under control. A CCP is under control if the hazard is eliminated or reduced to acceptable levels (Notermans *et al.*, 1995). This is a potential possible use of FMM in assisting HACCP teams.

4.23 MICROBIAL ANALYSIS OF MEAT

4.23.1 *C. perfringens*

Some hazards associated with the entire production process of tsire (a local kebab) were identified by Abdullahi *et al.* (2006) in three production centres. The aerobic plate count of organisms in tsire was from $\log_{10}$ 4.98 to $\log_{10}$ 6.27. Mould and yeast count had a range of $\log_{10}$ 1.77 to $\log_{10}$ 2.49. Staphylococcal counts in the raw meat were in the range of $\log_{10}$ 4.17–$\log_{10}$ 4.38 cfu/g. The average coliform count of the raw meat was in the range of $\log_{10}$ 4.65–$\log_{10}$ 5.25 cfu/g. Microbiological analyses showed tsire to have highest aerobic plate count of $\log_{10}$ 6.27; *Bacilluscereus* count was highest at $\log_{10}$ 3.30 cfu/g; *C. perfringens* count was highest at $\log_{10}$ 2.92 cfu/g; *Staphylococcal* count was highest at $\log_{10}$ 3.96 cfu/g; Coliform count was highest at $\log_{10}$ 4.08 cfu/g; yeast and mould count was highest at $\log_{10}$ 2.49 cfu/g. The proximate analysis showed tsire to averagely have 11.87% moisture, 31.77% protein, 23.16% fat and 2.43% salt. The critical appraisal of the production process indicated potential hazards in the raw meat, environmental contamination as well as post-process-handling contamination from humans and the environment. The nature of micro-organisms associated with tsire production as shown by this study calls for concern from the public health standpoint. In the light of this, efforts should be made by public health services with regard

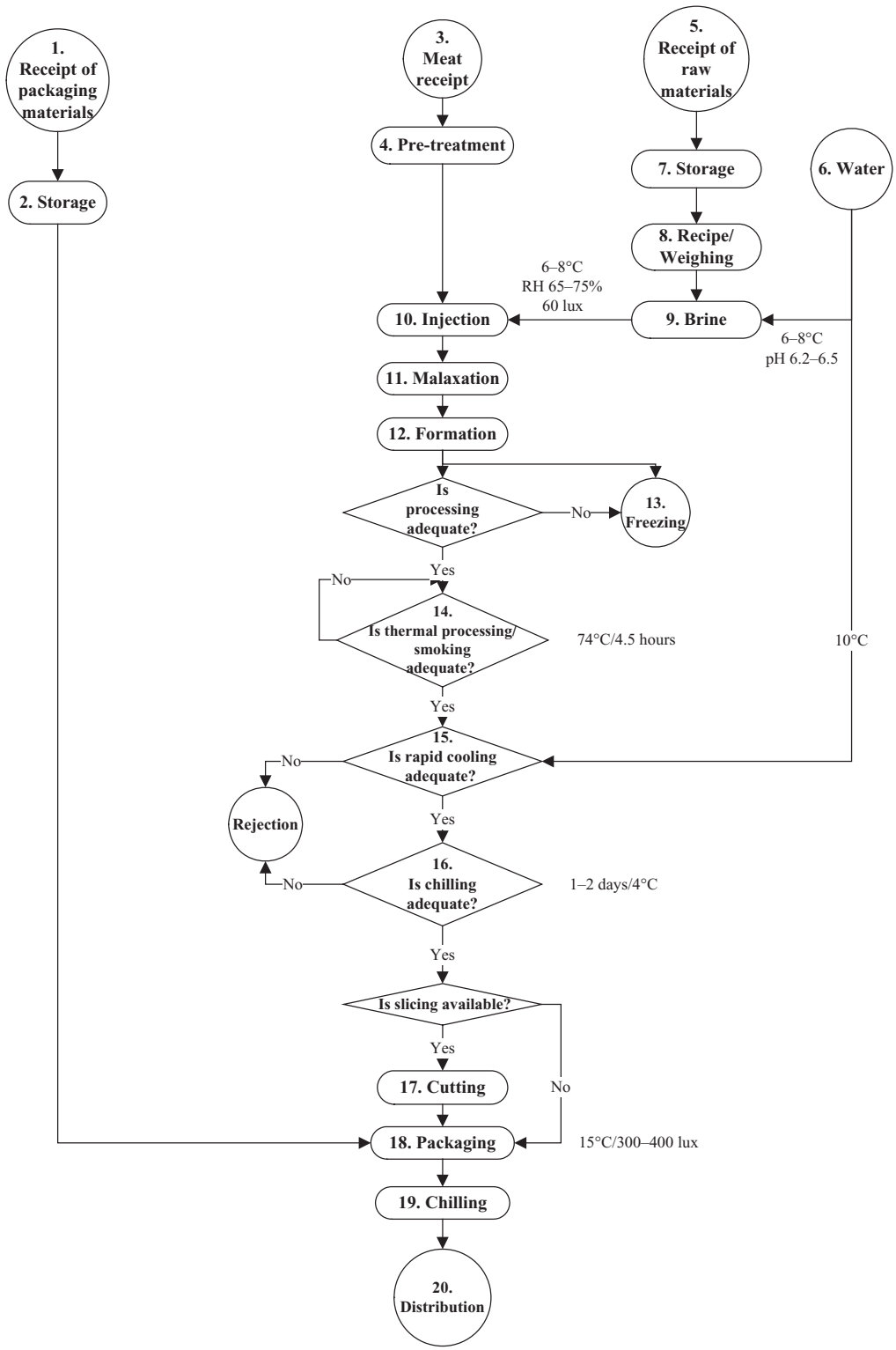

Fig. 4.10 Flow diagram of bacon production.

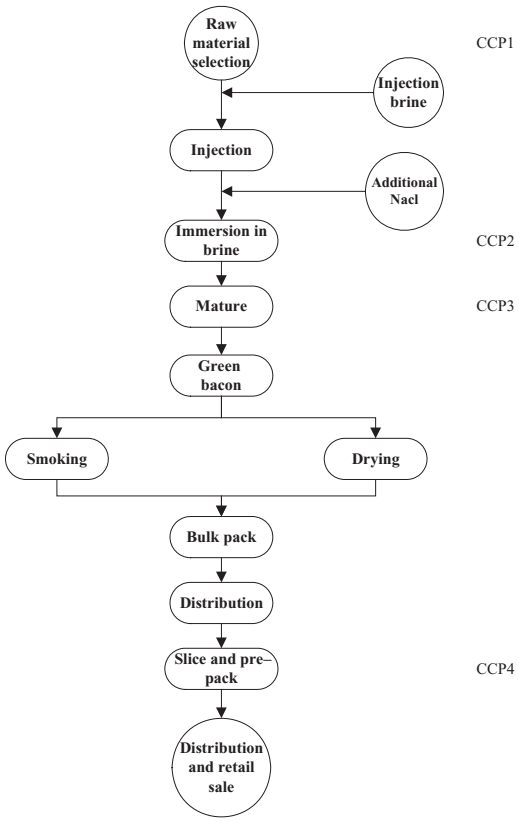

Fig. 4.11 Production of tank-cured Wiltshire bacon.

to improving its production in order to reduce the associated hazards.

4.23.2 Salmonella

Five-hundred and thirty general foodborne outbreaks of food poisoning reported in England and Wales between 1992 and 1996 were reviewed by Panisello *et al.* (2000) to study their application to the development and maintenance of HACCP systems. Retrospective investigations of foodborne disease outbreaks provided information on aetiological agents, food vehicles and factors that contributed to the outbreaks. *Salmonella* spp. and foods of animal origin (red meat, poultry and seafood) were most frequently associated with outbreaks during this period. Improper cooking, inadequate storage, cross-contamination and use of raw ingredients in the preparation of food were the most common factors contributing to outbreaks. Classification and cross tabulation of surveillance information relating to aetiological agents, food vehicles and contributory factors facilitate hazard analysis. In forming control measures and their corresponding critical limits, this approach focuses monitoring on those aspects that are critical to the safety of the product. Incorporation of epidemiological data in the documentation of HACCP systems provides assurance that the system is based on the best scientific information available.

The US FSIS tests sets of samples of selected raw meat and poultry products for *Salmonella* to ensure that federally inspected establishments meet performance standards defined in the Pathogen Reduction–Hazard Analysis and Critical Control Point (PR-HACCP) system final rule. In the report by Naugle *et al.* (2006) sample set results are described and associations between set failure and set and establishment characteristics are identified for 4607 sample sets collected from 1998 through 2003. Sample sets were obtained from seven product classes: broiler chicken carcasses ($n = 1010$), cow and bull carcasses ($n = 240$), market hog carcasses ($n = 560$), steer and heifer carcasses ($n = 123$), ground beef ($n = 2527$), ground chicken ($n = 31$) and ground turkey ($n = 116$). Of these 4607 sample sets, 92% (4255) were collected as part of random testing efforts (A sets), and 93% (4166) passed. However, the percentage of positive samples relative to the maximum number of positive results allowable in a set increased over time for broilers but decreased or stayed the same for the other product classes. Three factors associated with set failure were identified: establishment size, product class and year. Set failures were more likely early in the testing programme (relative to 2003). Small and very small establishments were more likely to fail than large ones. Set failure was less likely in ground beef than in other product classes. Despite an overall decline in set failures through 2003, these results highlight the need for continued vigilance to reduce *Salmonella* contamination in broiler chicken and continued implementation of programmes designed to assist small and very small establishments with PR-HACCP compliance issues.

The PR-HACCP final rule requires that all meat and poultry establishments implement science-based process controls designed to prevent or reduce significant food safety hazards, including microbiological hazards. There are four components to the PR-HACCP final rule that regulated establishments must address: SOPs for sanitation, HACCP plans, *E. coli* testing, and *Salmonella* performance standards. *Salmonella* was selected as the target bacteria for these performance standards because these bacteria are a leading cause of foodborne illnesses in humans, are commonly found in the enteric tracts of livestock and poultry, can be recovered from a variety of meat and poultry products using available methodologies, and require interventions

Table 4.33 Evaluation templates of the present risks for the critical control points (CCPs) determination for country sausages.

A/A	Process stage	Kind of risk	Potential hazards description	E1	Preventive actions	E2	E3	E4	α/α CCP
1	Materials receipt except meat	Biological	Contaminated/expired raw materials	Yes	Reliable suppliers/certificates control/labelling control	No	Yes	No	
		Biological	Raw materials receipt in inappropriate conditions		Quality control during the receipt:				
		Chemical	Pesticides residue, heavy metals.	Yes	Macroscopic (according to the work directive)	No	Yes	No	1
		Physical	Foreign bodies	Yes	Reliable suppliers	No	Yes	No	
2	Meat products receipt	Biological	Contamination due to deficient hygiene	Yes	Systematic sterilisation	No	Yes	No	
		Physical	Development of micro-organisms due to high temperatures	Yes	Air-conditioning and temperature control	No	Yes	No	
			Foreign bodies transport	Yes	GMP	No	Yes	No	
3	Materials storage except meat	Biological	Contamination due to deficient hygiene	Yes	Systematic sterilisation	No	Yes	No	
		Physical	Foreign bodies transport	Yes	GMP	No	Yes	No	
4	Grinding	Biological	Contamination due to deficient hygiene	Yes	Systematic sterilisation	No	Yes	No	
		Physical	Foreign bodies transport	Yes	GMP	No	Yes	No	
5	Preparation (vegetables washing, weighing, cutting)	Biological	Contamination due to deficient hygiene	Yes	Systematic sterilisation	No	Yes	No	
		Physical	Contamination due to deficient GMP and GHP	Yes	Wash with potable water	Yes			
			Foreign bodies transport	Yes	GMP	No	Yes	No	
6	Mixture	Biological	Contamination due to deficient hygiene	Yes	Systematic sterilisation	No	Yes	No	
		Physical	Foreign bodies transport	Yes	GMP	No	Yes	No	
7	Packaging in cases	Biological	Contamination caused by personnel and equipment	Yes	Systematic sterilisation of equipment and health conditions observance by the personnel	No	Yes	No	
		Physical	Foreign bodies transport	Yes	GMP	No	Yes	No	
8	Thermal process/smoking	Biological	Micro-organisms survival	Yes Yes	Monitoring of expected temperatures and times	Yes			2
9	Fast freeze with water	Biological	Inactivation of seeds which survived during the thermal process	Yes	Fast freeze with potable water	Yes			3
10	Weighing/labelling	Biological	Contamination caused by the environment, personnel and equipment	Yes	Systematic sterilisation of the equipment and personnel health conditions monitoring by the personnel	No	Yes	No	
		Physical	Foreign materials transport	Yes		No	Yes	No	
			Non-traceable product	Yes	GMP Label control before the release	No	Yes	No	
11	Freezing	Biological	Development of micro-organisms	Yes	Observance of temperature expected conditions	Yes			4
		Physical	Contamination caused by polluted storage areas	Yes	Systematic sterilisation	No	Yes	No	
12	Dispatch	Biological	Contamination caused by unclean trucks	Yes	Systematic sterilisation	No	Yes	No	5
			Development of micro-organisms due to temperature' inappropriate conditions	Yes	Temperature control/packing control	No	Yes	No	

Table 4.34 Summarical templates of HACCP monitoring of thermal process products.

Process stage	Potential risks description	Preventive actions	Executed controls	Critical limits	Responsible	Corrective action	Corr. act. responsible	Files – forms
Recipe/weighing	Addition of a lower than the required quantity of preservatives and salt Exceeding of the maximum permissible level of preservative	Recipe good evaluation/ balance function control/ preservatives periodic control	Salt and preservatives weighing	Salt at least 2.5% Phosphates content up to 0.2% and 0.3% for the rest of the meat products Nitrites up to 150 ppm Brine temperature up to 8°C (bacon)	Personnel Production Manager	Brine dissolving Or addition of other substances	Production manager	Production file
Infusion (bacon)	Smaller quantity of brine solution Exceed preservatives limit if a higher quantity of brine is added Fractured needles	Weigh control during the infusion Syringe control	Weight control during the infusion Syringe control	Infusion of all the provided quantity of brine solution Non fractured needle	Production Manager	Brine refilling Needle removal	Production Manager	Non-Compliance Registration Report, corrective and preventive actions Production file
Thermal process/ smoking	Incapacity of micro-organisms destruction	Monitoring of temperature and time expected conditions	Temperature and time control per lot	Centre temperature 74–75°C	Production manager	Thermal process prolongation	Production manager	Non-Compliance Registration Report, corrective and preventive actions Temperature registration file
Fast freeze with water	Spores growth	Rapid freezing with water	Temperature control at the centre of the product Water temperature control	T at the centre <37°C 10°C	Production manager	Product is transferred to the coolest point for refrigeration	Production manager	Non-Compliance Registration Report, corrective and preventive actions Temperatures registration file Production file

Table 4.35 Evaluation templates of the present risks for the critical control points (CCPs) determination for meat products from minced beef.

A/A CCP	Process stage	Kind of risk	Potential hazards description	Q1	Preventive actions	Q2	Q3	Q4	CCP
1	Packing receipt	Chemical	Inappropriate for foods (risk of migration)	Yes	Reliable suppliers	NO	Yes	No	2
		Physical/biological	Presence of dust and foreign matters	Yes	Certificates' control/6 months Labelling control	NO	Yes	Yes	
					Macroscopic control				
2	Receipt of other raw materials	Biological	Contaminated/expired raw materials	Yes	Reliable suppliers/certificates' control/labelling control	No	Yes	No	2
		Biological	Raw materials collection in suitable conditions		Quality control during the receipt:				
		Chemical	Antibiotics and pesticides residues, heavy metals.	Yes	Macroscopic (according to the work directive)	No	Yes	No	
		Physical	Foreign bodies	Yes	Reliable suppliers	No	Yes	No	
3	Temporary packing	Biological	Contamination caused by personnel and equipment	Yes	Systematic sterilisation of the equipment and observance of the hygiene conditions by personnel	No	Yes	Yes	
		Physical	Packing in polluted containers	Yes	Control of containers and product quality	No	Yes	Yes	
			Transport of foreign matter	Yes	GMP	No	Yes	Yes	
4	Packing storage	Biological	Contamination due to deficient hygiene	Yes	Systematic sterilisation	No	Yes	Yes	
		Physical	Foreign bodies transport	Yes	GMP	No	Yes	Yes	
5	Storage of other raw materials	Biological	Development of micro-organisms	Yes	Monitoring of the temperature expected conditions	Yes			3
		Physical	Contamination due to polluted storage spaces	Yes	Systematic sterilisation				
					Control of expiration date and FIFO observance	No	Yes	No	
6	Preparation (wash, cut etc.)	Biological	Contamination due to personnel and equipment	Yes	Good industrial practice, systematic sterilisation	Yes			
			Remaining of pesticides residues						
		Chemical	Incapacity of foreign bodies removal	Yes	Vegetables' good rinse	Yes			
		Physical		Yes	Good industrial practice	Yes			
5, 7	Meat and other raw materials freeze	Biological	Development of micro-organisms	Yes	Observance of the temperature expected conditions	Yes	Yes	No	3
		Physical	Contamination by polluted storage areas	Yes	Products coverage	NO			
					Systematic sterilisation				
					Control of expiration date and FIFO observance				

8–12	Grinding–filling	Biological	Cross-contamination caused by personnel and equipment/surfaces	Yes	Correct practice/ Cleansing/Sterilisation' equipment	No	Yes	No	
		Biological	Growth of microorganisms due to defective control of temperature and time outside the refrigerator	Yes	Control of the space/product temperature				
		Physical	Remains of bones and foreign matter	Yes	Stay outside the refrigerator up to 1 hour/control during the process				
13	Fast cold storage	Biological	Low rythme "rapid" cooling	Yes	Control of temperature function blast chiller	Yes			5
					Control of temperature at the centre of product				
					Control of entrance – exit from the tunnel				
14	Packing/labelling	Biological	Contamination caused by personnel and equipment	Yes	Systematic sterilisation of the equipment and observance of the hygiene conditions by the personnel	No	Yes	No	
		Physical	Packing in polluted containers	Yes	Control of containers	No	Yes	No	
			Foreign materials transport	Yes	GMP	No	Yes	No	
			Non-traceable product		Label control before the release				
15	Freeze/cold storage	Biological	Development of micro-organisms	Yes	Observance of the temperature expected conditions	Yes			6
		Physical	Contamination by polluted storage areas	Yes	Systematic sterilisation				
					Control of expiration date and FIFO observance	No	Yes	No	
16	Transportation	Biological	Pollution caused by unclean trucks	Yes	Systematic sterilisation	No	Yes	No	7
			Development of micro-organisms due to high temperature'	Yes	Temperature control/packing control	Yes			
			Loading of inappropriate products						

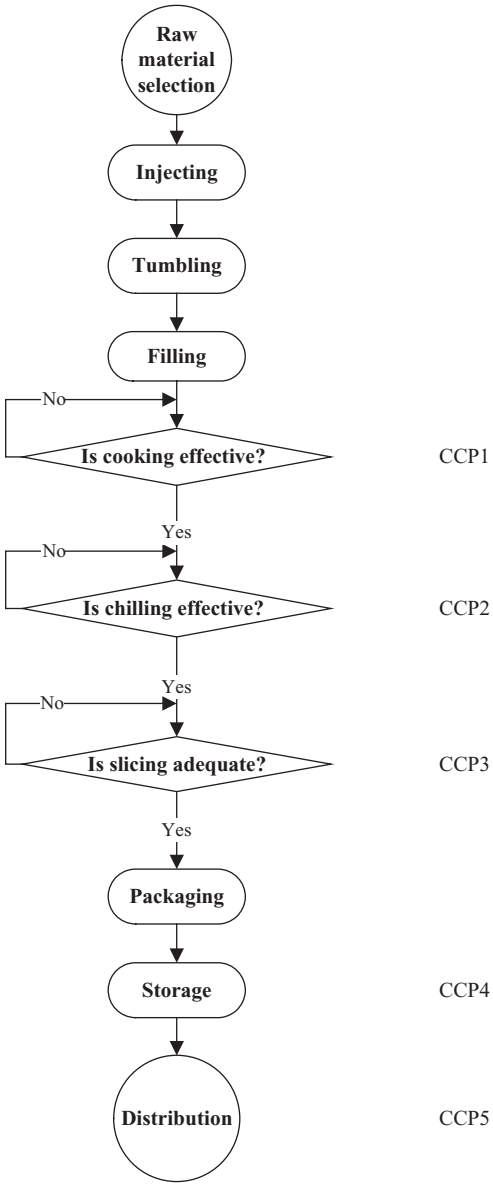

Fig. 4.12 Production of packaged sliced ham from canned ham.

that would concomitantly be effective against other pathogens.

The role of establishment size in set failure may be related to the ability of large establishments to implement certain pathogen reduction strategies that are cost prohibitive for smaller establishments or their ability to assign specific personnel to ensure PR-HACCP compliance. Other explanations may include factors such as variability in evisceration techniques, limited space between clean and unclean areas, and multiple cuts on the same carcasses by individual workers in low-capacity establishments (Hansson, 2001). The need to address these variables should drive the continued development and implementation of FSIS programmes designed to assist small and very small establishments with PR-HACCP compliance issues (Naugle *et al.*, 2006).

The design of a HACCP-like approach to the control and prevention of salmonellosis on meat-pig farms (e.g. *S. typhimurium* and *S. enterica* spp.) has been described by Noordhuizen and Frankena (1999). Applying risk-management principles to animal health must include the control of risks related to the introduction of the pathogen into the farm and the control of risks related to the spread of the pathogen within the farm once introduced but also the control of risks related to the emission of the pathogen from the farm.

For reasons of clarity and simplicity, the pig-production chain has been reduced to the sequence of multipliers, pig farm and other farms or slaughterhouse. Growth farms are provided with pigs from the breeder farms, while foodstuff is supplied to all farms through feed mills. Fattened pigs are delivered to either other farms or slaughterhouse, after which the processing takes place and carcasses or products are further transported to retailer and consumer.

The risk factors and conditions related to the introduction of salmonellae into the pig farm have been described in the literature and can be divided into two categories:

1. Risk conditions which are more general in nature and also apply to other infections, and
2. Specific risk conditions related to the introduction of the given pathogen.

The latter are associated with the balance between infection burden in the environment and host resistance against diseases. Purchased feedstuff is generally regarded as one of the most important factors contributing to a higher risk of introduction of salmonellae in pig farms. GMP-produced feed will considerably lower that risk. Another factor of high importance is the purchase of piglets from growth farms, especially infected or carrier piglets. In this situation too, it would be appropriate if such a delivery would be accompanied by a salmonella-free health certificate to lower the risk, or with an adequate disease history report to reduce the risk. This would also decrease the risk of cross-infection during stressful transportation, during which animals apparently shed to a greater extent.

The next important factor relates to farm-management practices. Here, the farmer can contribute significantly to a lower risk by applying good farming practice (GFP) and good hygiene practice (GHP) (e.g. by keeping his farm as closed as possible Noordhuizen and Frankena, 1999).

For the control of transmission of salmonellae within a farm, interrelated conditions are included such as feedstuff, feed leftovers and the feeding system. Among the most relevant conditions are feeding system, visitors, animal reallocation and hygiene status. A strictly applied hygiene strategy could substantially reduce the number of infections on a farm. For visitors it seems highly appropriate that codes of good animal health practice and good hygiene practice are adopted. Different materials and equipment sets should be available for each separate house. Reallocation of pigs from different pens should be avoided and manure handling should be done properly. Check-ups on salmonella status of pigs can be made on arrival of pigs, during the production process (of fattening) and at delivery. Diagnostic-test characteristics are of paramount importance in infectious disease events and the issue of carriers should be addressed repeatedly. On delivery at the slaughterhouse, a proper health certificate should accompany the batch of meat-pigs.

The following times and temperatures should be considered potential critical limits according to Ingham *et al.* (2004) for preventing the growth of *Salmonella* serovars and *E. coli* O157:H7 on raw meat and poultry: products can be exposed to temperatures between 5 and 10°C for less than 8 hours or to temperatures between 5 and 22°C for not more than 2 hours.

Except for a 0.2 log cfu increase in *Salmonella* serovars in ground beef during 2 hours at room temperature, pathogens did not grow. Results of trials with commercial amounts of beef, pork, chicken, ground beef and bratwurst exposed to 10°C for eight hours or 22°C for two hours also showed no pathogen growth (Ingham *et al.*, 2004).

During the 1990s, there were radical changes in regulation of meat and poultry hygiene in Australia, and Australian Standards were developed for each sector of the meat industry. Systems for industry/government co-regulation and company-employed meat inspection were introduced based on company HACCP programmes approved and audited by the Controlling Authority. However, in the five years since regulatory changes took full effect, rates of salmonellosis have not decreased (surveillance and reporting systems have remained unchanged). Using statistics gathered by the National Enteric Pathogens Surveillance Scheme, an attempt was made to link *Salmonella* serovars isolated from meat and poultry with those causing salmonellosis. Two periods were studied, 1993/1994, before regulations were introduced, and 2000/2001, when regulations should be having an effect (Sumner *et al.*, 2004). For red meat, the same serovars were prominent among the top ten isolates both before and after regulation, and there was little linkage with salmonelloses. For poultry, frequently isolated serovars differed pre- and post-regulation, however, in both periods there was some linkage between serovars isolated from poultry and those causing salmonelloses. Using published and unpublished survey data, it was concluded that there had been improvements in microbiological quality of red meat and poultry over the same time frame as regulatory changes. These improvements apparently have not carried through to reduced case-rates for salmonellosis may be due to numerous causes, including lack of control in the food processing, food service and home sectors.

Serotype-matching has been used in two US studies. Schlosser *et al.* (2000), as part of the implementation of the USA Pathogen Reduction Program, documented the prevalence of *Salmonella* serovars in carcase and ground beef, pork and poultry. For each product there was some commonality between serovars on carcass surfaces and in ground products. However, there was little commonality between serovars in raw meats (carcass/ground meats) and those from patients.

Sarwari *et al.* (2001) compared serovars isolated from meat and poultry over the period 1990–1996 with serovars involved in salmonellosis in USA. Like Schlosser *et al.* (2000) these authors found little concurrence when attempting to match serovar prevalence in meats with human cases. For example, *S. kentucky* was found in beef, pork and chicken, sometimes at high prevalence, and yet caused only 0.1% of cases compared with an 'expected' involvement of 14%. Sarwari *et al.* (2001) modelled the 'ability to cause human illness' for each serovar.

There have been improvements in TVC and prevalence of *E. coli* and *Salmonella* over the period 1994–2002. For beef and sheep carcasses, mean TVCs have fallen by 2 log scales, while prevalence of *E. coli* has also fallen markedly. Prevalence of *Salmonella* on sheep carcasses was also much lower in 2002 compared with 1994, though on beef carcasses there has been little change from the low (0.34%) prevalence in 1994.

Increased consumer awareness and concern about microbial foodborne diseases has resulted in intensified efforts to reduce contamination of raw meat, as evidenced by new meat and poultry inspection regulations being implemented in the USA. In addition to requiring operation of meat and poultry slaughtering and processing plants under the principles of the HACCP

system, the new regulations have established microbiological testing criteria for *E. coli* and *Salmonella*, as a means of evaluating plant performance. These developments have renewed and intensified interest in the development and commercial application of meat and poultry decontamination procedures.

Technologies developed and evaluated for decontamination include live animal cleaning/washing, chemical dehairing, carcass knife-trimming to remove physical contaminants, steam/hot water vacuuming for spot-cleaning/decontamination of carcasses, spray washing/rinsing of carcasses with water of low or high pressures and temperatures or chemical solutions, and exposure of carcass sides to pressurised steam as described by Sofos and Smith (1998). Under appropriate conditions, the technologies applied to carcasses may reduce mean microbiological counts by approximately one–three log colony forming units (cfu)/cm^2, and some of them have been approved and are employed in commercial applications (i.e., steam-vacuuming; carcass spray-washing with water, chlorine, organic acid or trisodium phosphate solutions; hot water deluging/spraying/rinsing, and pressurised steam). The contribution of these decontamination technologies to the enhancement of food safety will be determined in the long term, as surveillance data on microbial foodborne illness are collected.

Berends *et al.* (1998b) described the contamination of pork with *Salmonella* spp. in cutting plants and butchers' shops in the Netherlands and quantified the influence of several risk factors. When contaminated carcasses are being processed, the main risk factors regarding cross-contamination are inept cleaning and disinfection (OR 12.8), manipulation of contaminated materials as such (OR 4.7) and (re)contaminated surfaces (OR 4.4). However, in the current situation, where contaminated carcasses are constantly being brought into cutting lines, interim cleaning and disinfection of surfaces and utensils during breaks and at the end of the working day will most likely prevent not more than about 10% of all cross-contamination that takes place during a working day. Thus, as long as contaminated carcasses are being processed, about 90% of the cross-contamination that occurs in cutting plants is practically unavoidable. It can be therefore concluded that under these circumstances the implementation of codes of good manufacturing practices (GMPs) and HACCP-inspired production methods will only be marginally effective in the control of *Salmonella* spp. cross-contamination in cutting lines. The same is more or less true for the processing of contaminated cuts or carcasses by butchers in shops and supermarkets. Furthermore, in contrast to the situation in cutting plants, it may be that up to 10% of butcher's shops or kitchens of restaurants become colonised for several weeks or months with their own endemic 'house flora' of *Salmonella* spp., which are originally introduced via the purchased contaminated products of animal origin.

Without a more thorough knowledge about the diagnostic value of current and future methods of sampling and identification, it is impossible to provide more accurate estimations of the prevalence of *Salmonella* positive carcasses and cuts. Based on the research data, the incidence of contaminated cuts and retail-ready pork cannot be estimated more precisely than as somewhere between 5 and 40%. When compensating for the discussed methodological flaws, it must be assumed that currently the true prevalence of contaminated primal cuts and retail-ready pork in butchers' shops is about 25–30%, and that of minced pork and pork sausages about 50–55%. Lastly, it is concluded that if carcasses were *Salmonella* free, consumers could in principle be provided with virtually *Salmonella*-free pork. It is therefore recommended that the EU allows for a decontamination step in slaughterhouses with a substance that is generally recognised as safe, provided that the producers strictly adhere to GMP principles.

4.23.3 E. coli and Enterobacteriaceae

E. coli O157:H7 is an important verotoxin-producing enterohaemorrhagic *E. coli* associated with HUS, thrombotic thrombocytopenic purpura and haemorrhagic colitis in humans (Philips, 1999). Cattle appear to be the major reservoir since most of the foodborne infections due to *E. coli* O157:H7 have been associated with foods of bovine origin, particularly ground beef and raw milk. *E. coli* O157:H7 has several virulence factors such as verotoxins (VT1 and VT2), eaeA (intimin) and enterohaemolysin (Law, 2000). Verotoxins produced by *E. coli* O157:H7 are very similar to those produced by *Shigella dysenteriae* type 1 and those called Shiga-like toxins. VT1 and VT2 are different proteins and encoded by different sets of genes but their active molecular structure and biological functions are similar. Verotoxins inactivate ribosomal RNA, inhibit protein synthesis and they eventually cause the death of host cells.

Yilmaz *et al.* (2006) aimed at detecting VT1, VT2 and eaeA genes and to determine the frequency of these genes in *E. coli* O157 and O157:H7 strains isolated from cattle, cattle carcasses and environmental samples of the five abattoirs located in Istanbul, Turkey. Therefore, the presence of VT1, VT2 and eaeA genes

in 26 strains of *E. coli* O157:H7 and six strains of O157 were investigated by multiplex-PCR. The results have shown that eaeA gene was detected in all O157 and O157:H7 strains tested. Both VT2 and eaeA genes were detected in four (80%) of five strains of *E. coli* O157 and eaeA alone in one strain of O157. In 27 strains of O157:H7, 5 (18.5%) strains were found to be positive for VT1, VT2 and eaeA genes, 19 (70.3%) strains for both VT2 and eaeA, and three (11.1%) strains for only eaeA gene. Either VT1 alone or VT2 alone was not detected in any strains tested. eaeA gene alone in two strains, VT2–eaeA genes in nine strains and VT1–VT2–eaeA genes in two strains were detected in 13 of *E. coli* O157:H7 strains isolated from cattle. eaeA alone in one strain, VT2–eaeA genes in five strains and VT1–VT2–eaeA genes in two strains were detected in eight of *E. coli* O157:H7 strains isolated from carcasses. VT2–eaeA genes in five strains (isolated from hands, apron, knife and floor) and VT1–VT2–eaeA genes in one strain (isolated from knife) were also detected in six of *E. coli* O157:H7 strains isolated from environmental samples. This study revealed that most of the strains are found to be toxigenic and it is most likely that strains isolated from carcasses and abattoir environments originated from cattle faeces. Therefore, HACCP systems are necessary from farm to table especially in the abattoirs to prevent contamination of meat and abattoir environment with intestinal content.

During the period 2001–2002, a total of 236 inspections were performed on 27 catering establishments in the province of Ferrara (Emilia-Romagna region, Italy), after a HACCP system was introduced and educational programmes for food staff were undertaken for approximately ten years. A total of 370 food samples and 140 surface swabs were taken and examined for microbiological quality (Legnani *et al.*, 2004).

The surveillance system has brought to light various shortcomings regarding the equipment (36 corrective actions) and incorrect procedures (47 corrective actions). The tool and work surfaces showed an unacceptable contamination in 10% of samples. The data also highlighted a certain percentage of unacceptable samples of foods, especially with regard to *E. coli*, ranging from 5.4% for the 'first and second courses' to 10.8% for the 'raw meats and meat preparations'. Nevertheless, the hygienic quality of services and foods has improved in comparison with previous surveys, showing that the staff educational programmes and the application of HACCP principles have increased the level of awareness regarding food hygiene in those working in catering services.

The impact on human health of *Salmonella* spp. on pork in the Netherlands is described by Berends *et al.* (1998a). Subsequently, the effects of some proposed control strategies in the Dutch pork production chain are evaluated and quantified with the aid of a simple mathematical model. The estimated average incidence of cases of salmonellosis in the Netherlands is about 450 cases per 100,000 person years at risk (per year). Some special risk groups for which the risks could be quantified are (1) persons with underlying diseases, such as neoplasms or diabetes mellitus (1200 cases/100,000 per year); (2) persons with achlorhydria or who excessively use antacids (1100 cases/100,000 per year); (3) persons who have recently been treated with antibiotics that disturb the normal gut flora (1700 cases/100,000 per year); (4) nurses (900 cases/100,000 per year); (5) caterers (900 cases/100,000 per year); and (6) slaughter line personnel (1800 cases/100,000 per year). Furthermore, it is estimated that 15% (5–25%) of all cases of salmonellosis in the Netherlands are associated with the consumption of pork. Currently, proposed control measures regarding *Salmonella* in pigs and on pork in the Netherlands are codes of GMPs that, in fact, formalise recommendations that can be found in many handbooks about pig breeding and pig slaughtering.

When evaluated by a mathematical model constructed for this purpose, the proposed GMP codes from farm to cutting/retail could, at best, reduce the current levels of *Salmonella*-positive pigs and pork by 50–60%. If pigs were bred according to the rather costly specific pathogen-free concept (SPF), the prevalence of contaminated carcasses and pork could in total be reduced by 95% or more. However, implementing GMP codes from the transport phase up to the cutting/retail phase coupled with a decontamination step at the end of the slaughter line would be just as effective as GMP in combination with breeding using the SPF concept. It was therefore concluded by Berends *et al.* (1998a) that the most efficient and cost-effective way of reducing the '*Salmonella* problem' entailed by the consumption of pork would be to decontaminate carcasses under the precondition that the entire production chain strictly adheres to GMP principles. Therefore, the EU should also allow for more possibilities regarding the decontamination of carcasses than is currently the case. It is also concluded that existing EU regulations relying on HACCP-inspired production in abattoirs are effective in reducing the prevalence of *Salmonella* spp. on pork. This is mainly because (1) there is an almost steady stream of *Salmonella*-positive carcasses that enter the cutting process; (2) when contaminated carcasses are being processed, further

cross-contamination during working hours is unavoidable; and (3) no steps in the cutting process are intentionally designed to reduce the risks of cross-contamination of cuts and retail-ready products.

Juska *et al.* (2003) outlined a conceptual framework for examining recent outbreaks of *E. coli* O157:H7 infection associated with the consumption of beef in the USA. They argued that beef produced in this country is generally safer from bacteriological contamination than in the past. Paradoxically, increasing intensification and concentration in the meat subsector since the early 1980s has (a) altered agro-food ecology, including characteristics of foodborne bacteria and human physiology; (b) created conditions favourable for the rapid amplification of low concentrations of pathogens; and (c) reduced the beef industry's flexibility for introducing the changes necessary to preclude and/or control the rapid spread of pathogens in meat and meat products. As a result, the beef industry currently is capable of producing large quantities of bacteriologically safe meat while simultaneously becoming more vulnerable to food contaminations that can be fatal in some cases. The limitations and effectiveness of a new regulatory regime, the HACCP systems, are decontaminating the meat supply and reducing foodborne disease outbreaks.

A total of 523 chilled beef and lamb carcasses were sampled from four abattoirs and 13 very small plants (VSPs) in South Australia during March 2002 in order to develop a microbiological profile of meat produced for domestic consumption within the State (Sumner *et al.*, 2003). Aerobic viable counts (AVCs) and *E. coli* counts were obtained from samples taken by sponge-sampling the muscle-adipose tissue at sites designated for each species in the Microbiological Guidelines to the Australian Standard for Hygienic Production of Meat for Human Consumption (identical with those of the USA Pathogen Reduction: Hazard Analysis and Critical Control Point [HACCP] Systems: Final Rule). On beef carcasses ($n = 159$) mean log AVC/cm^2 was 1.82 and *E. coli* was detected on 18.8% of carcases (area sampled 200 cm^2) for which the mean log of the positives was -0.34; for lamb carcasses, on which 75 cm^2 was sampled ($n = 364$), corresponding values were 2.59, 36.2% and $\log_{10}$ 0.27, respectively. There was little difference in mean log AVC/cm^2 of carcasses produced at abattoirs and VSPs, 1.72 versus 1.81, respectively, for beef, and 2.80 versus 2.44, respectively, for sheep. Prevalence of *E. coli* was lower at VSPs, however, with abattoirs having 28.4% for beef and 61.5% for sheep, compared with corresponding values of 4.7 and 18.5% at VSPs. In VSPs, the range of mean log AVC/cm^2 was 0.47–3.16 for beef and 1.63–3.65 for sheep carcasses, data which will allow the Controlling Authority to assist plants to improve performance of slaughter and dressing techniques.

Thirty-six carcasses were sampled by McEvoy *et al.* (2004) over a 12 months period at an Irish beef abattoir. Between one and five carcass sites (including the hock, brisket, cranial back, bung, inside round and outside round) were sampled after hind leg skinning, hide removal, bung tying, evisceration, splitting, washing, chilling for 24 hours and boning, using a wet and dry, cotton wool swab technique. For each sample, TVC, *E. coli*, total coliforms and *Enterobacteriaceae* were enumerated. The results were considered in relation to EU Decision 2001/471/EC which sets performance criteria for TVCs and *Enterobacteriaceae* in samples taken by excision. Though not explicitly stated in the Decision, it has been proposed that microbiological performance criteria for samples taken by swabbing be set at 20% of the values set for excision samples. Therefore, log mean TVCs in carcass swab samples taken before chilling are acceptable, marginal and unacceptable when they are <2.8, 2.8–4.30 and >4.30 cm^{-2}, respectively. By these criteria, TVCs on carcasses in the McEvoy *et al.* study were in the marginal range. The marginal result for TVCs was due in the most part to hide removal operations, particularly at the hock and brisket sites. Bacterial contamination on post-chill carcasses was similar or lower to that on pre-chill carcasses, while boning resulted in general increases in TVCs and in *E. coli*, total coliform and Enterobacteriaceae numbers. In the Decision 2001/471/EC, the effects of chilling and boning are not included in the assessment of process control. Data from this study indicate that performance criteria based on log mean *Enterobacteriaceae* values are unsuitable because of the infrequent occurrence of these organisms on the carcass.

Decontamination of meat or carcasses may have an effect in reducing the number of pathogens. Recontamination with other pathogens during cutting or packaging may, however, result in higher growth on decontaminated than on untreated meat due to the lack of competing non-pathogenic micro-organisms. Nissen *et al.* (2001) compared the growth of pathogens during storage at 10°C (worst case condition) on untreated meat and meat that had been decontaminated by steam vacuuming combined with spraying with 0.2 M lactic acid.

The increased growth of *E. coli* O157:H7 on decontaminated beef, especially when vacuum packed, gives cause for concern. Preventive measures might be a strict HACCP approach to the handling of the decontaminated meat before packaging or use of a protective

culture of LAB. Growth of *S. enteritidis* on chicken and *Yersinia enterocolitica* on pork skin was not significantly higher on decontaminated compared to untreated meat.

Thermal inactivation of a four-strain mixture of *E. coli* O157:H7 was determined in 90% lean ground beef and lean ground chicken by Juneja *et al.* (1997). Inoculated meat was packaged in bags which were completely immersed in a circulating water bath and held at 55, 57.5, 60, 62.5, and 65°C for predetermined lengths of time. *D* values, determined by linear regression, in beef were 21.13, 4.95, 3.17, 0.93 and 0.39 minutes, respectively ($z = 6$°C). Using a survival model for non-linear survival curves, *D* values in beef ranged from 20.45 minutes (D_1 and there was no D_2) at 55°C to 0.16 minutes (D_1) and 1.45 minutes (D_2) at 65°C. When *E. coli* O157:H7 four-strain cocktail was heated in chicken, *D* values calculated by both approaches were consistently less at all temperatures. The heat resistance of *E. coli* O157:H7 was not altered after refrigerated or frozen storage of inoculated beef for 48 hours. The results of this study are beneficial to the food industry in designing HACCP plans to effectively eliminate *E. coli* O157:H7 in the meat products used in this study.

4.23.4 Campylobacter

A total of 825 samples of retail raw meats (chicken, turkey, pork, and beef) were examined for the presence of *E. coli* and *Salmonella* serovars by Zhao *et al.* (2001) and 719 of these samples were also tested for *Campylobacter* spp. The samples were randomly obtained from 59 stores of four supermarket chains during 107 sampling visits in the Greater Washington, DC, area from June 1999 to July 2000.

A total of 722 *Campylobacter* isolates were obtained from 159 meat samples; 53.6% of these isolates were *C. jejuni*, 41.3% were *Campylobacter coli*, and 5.1% were other species. Nineteen per cent of the beef samples and 16.3% of the pork samples were positive for *E. coli*.

This study revealed that retail raw meats are often contaminated with foodborne pathogens; however, there are marked differences in the prevalence of such pathogens in different meats.

Quantitative risk assessment (QRA) is a methodology used to organise and analyse scientific information to estimate the probability and severity of an adverse event. Applied to microbial food safety, the methodology can also help to identify those stages in the manufacture, distribution, handling, and consumption of foods that contribute to an increased risk of foodborne illness, and help focus resources and efforts to most effectively reduce the risk of foodborne pathogens. The term process risk model (PRM) was introduced by Cassin *et al.* (1998) to describe the integration and application of QRA methodology with scenario analysis and predictive microbiology to provide an objective assessment of the hygienic characteristics of a manufacturing process. The methodology was applied to model the human health risk associated with *E. coli* O157:H7 in ground beef hamburgers. The PRM incorporated two mathematical submodels: the first was intended to describe the behaviour of the pathogen from the production of the food through processing, handling and consumption to predict human exposure. The exposure estimate was then used as input to a dose–response model to estimate the health risk associated with consuming food from the process. Monte Carlo simulation was used to assess the effect of the uncertainty and variability in the model parameters on the predicted human health risk. The model predicted a probability of haemolytic uraemic syndrome of 3.7×10^{-6} and a probability of mortality of 1.93×10^{-7} per meal for the very young. These estimates are likely high for all hamburger meals, but may be reasonable for the home-prepared hamburgers described by this model.

The efficacy of three risk mitigation strategies was evaluated by modifying the values of the predictive factors and comparing the new predicted risk. The average probability of illness was predicted to be reduced by 80% under a hypothetical mitigation strategy directed at reducing microbial growth during retail storage through a reduction in storage temperature. This strategy was predicted to be more effective than a hypothetical intervention which estimated a plausible reduction in the concentration of *E. coli* O157:H7 in the faeces of cattle shedding the pathogen and one aimed at convincing consumers to cook hamburgers more thoroughly. The conclusions of this approach are only accurate to the extent that the model accurately represents the process. Currently, uncertainty and ignorance about the hygienic effects of the individual operations during production, processing and handling limit the applicability of a PRM to specify HACCP criteria in a quantitative manner. However, with continuous improvement through stimulated research, a PRM should encompass all available information about the process, food and pathogen.

4.23.5 Enterococci

The presence of enterococci in the gastrointestinal tract of animals leads to a high potential for contamination

of meat at the time of slaughter. Enterococci were consistently isolated from beef, poultry or pig carcasses or fresh meat in studies of antibiotic resistance of enterococci (Aarestrup *et al.*, 2002; Davies and Roberts, 1999; Klein *et al.*, 1998; Mac *et al.*, 2002). Not only do enterococci contaminate raw meats, they are also associated with processed meats. Heating of processed meats during production may confer a selective advantage on enterococci because these bacteria are among the most thermotolerant of the non-sporulating bacteria (Magnus *et al.*, 1988).

After surviving the heat-processing step, both *Enterococcus faecalis* and *E. faecium* have been implicated in spoilage of cured meat products, such as canned hams and chub-packed luncheon meats (Bell and DeLacey, 1984; Magnus *et al.*, 1986). They are considered very important for ripening and aroma development of certain traditional sausages, especially those produced in the Mediterranean area. Enterococci are also used as human probiotics. However, they are important nosocomial pathogens that cause bacteraemia, endocarditis and other infections. Some strains are resistant to many antibiotics, but antibiotic resistance alone cannot explain the virulence of some of these bacteria. Virulence factors such as adhesins, invasins and haemolysin have been described. The role of enterococci in disease has raised questions on their safety for use in foods or as probiotics. Studies on the incidence of virulence traits among enterococcal strains isolated from food showed that some harbour virulence traits and generally, *E. faecalis* harbours more of them than *E. faecium*.

In general, *E. faecium* appears to pose a lower risk for food, because these strains generally harbour fewer recognised virulence determinants than *E. faecalis*. Generally, the incidence of such virulence determinants among *E. faecium* strains is low, as compared to *E. faecalis* strains, probably as a result of the presence of pheromone-responsive plasmids (Franz *et al.*, 2003).

Enterococci have also been isolated from some types of fermented sausages. Salami and Landjäger were shown to contain enterococci at numbers ranging from 100 to 2.6×10^5 cfu/g (Teuber *et al.*, 1996). Enterococci were isolated from dry fermented sausages known as 'chorizo' (Casaus *et al.*, 1997; Cintas *et al.*, 1997) and 'espetec' (Aymerich *et al.*, 1996), produced in Spain.

Enterocins A and B from *E. faecium* CTC492 (Aymerich *et al.*, 1996), when added as semi-pure preparations, showed a marked antilisterial activity in model meat and meat products such as cooked ham, minced pork meat, deboned chicken breasts, paté and 'espetec'.

4.23.6 BSE

The control measures for the CCPs were:

- imposing a feed ban on meat and bone meal to prevent bovine spongiform encephalopathy (BSE);
- withholding stock from slaughter to ensure there is no violation of maximum residue limits with agricultural and veterinary chemicals; and
- avoiding grazing of land treated with human effluent to avoid infection with *Cysticercus bovis* (beef measles).

An example of the effective control of risk through good agricultural practice (GAP) is control of BSE risks. In Australia there has been a complete ban on feeding of animal products to ruminants since 1997, which followed a ban on the importation of meat and bone meal since 1966 (except from New Zealand). Verification of the effectiveness of the GAP feeding ban at the industry level is the nil detection of BSE by the National Transmissible Spongiform Encephalopathy (TSE) Surveillance Program (Animal Health Australia) since 1998.

Tables 4.36–4.38 were compiled to provide a generic framework to cover all species and production systems within the scope. Verification of the process flowchart and the activities in Table 4.36 was undertaken by desktop review by industry stakeholders, including members of the respective meat and livestock industry peak councils and other industry groups (Horchner *et al.*, 2006).

The risk profile project identified over 40 different biological, physical and chemical hazards and potential hazards associated with the red meat industry (Table 4.37; Meat and Livestock Australia, 2003a,b). A substantial number of control points were identified for a range of hazards and potential hazards which were found to be managed through the application of GAP. An extract of examples is provided in Table 4.38 with full details published in Meat and Livestock Australia (2003c). The application of GAP particularly applies to appropriate use of veterinary chemicals in animals, on pastures and in feedstuffs fed to animals as well as physical hazards such as broken needles.

In relation to the identified microbiological hazards, indicator organisms were identified as requiring consideration in an on-farm food safety programme. As a measure of process hygiene indicator organisms are monitored as a part of regulatory testing in meat-processing plants. Although levels of indicator bacteria such as *E. coli*, coliforms and TVC have established weak links with pre-slaughter cleanliness of livestock in some studies (McEvoy *et al.*, 2000), the complexity of developing effective

Table 4.36 Activities associated with each step in livestock production process flow diagram.

Process steps	Activities associated with this step	Species differences
1 Animals born on property	Establish identification and traceability of animals	Individual vs. mob/property
2 Introduced livestock	Purchase or obtain animals	May include feral animals for each species
	Receipt of animals	
	Establish identification and traceability of animals	Individual vs. mob/property
3 Production system	Historical/previous land use	
	Contaminants from external enterprises	
	Intensive vs. extensive system (includes range fed, supplementary fed, dairy farms and hobby farm systems and feral animal harvesting)	Possible range of production systems for each species
4 Husbandry practices	Mating/breeding and reproduction programme, including pregnancy testing, weaning	Variable use of artificial insemination and artificial breeding
	Marking	Branding vs. other identification methods
	Handling—mustering, yarding	
	Movements—on property, between properties, droving	Dehorning; shearing, crutching, mulesing, milking
	Manage nutritional requirements	
	Animal health programme	Dipping; drenching; injecting; vaccinating
	Culling, euthanasia and carcass disposal	
5 Pastures and cropping	Manage pasture and/or crop quality	
	Purchase pasture and/or crop treatment chemicals	
	Receival of pasture and/or crop treatment chemicals	
	Storage of pasture and/or crop treatment chemicals	
	Preparation of pasture and/or crop treatment chemicals	
	Approval of pasture and/or crop treatment for use	
	Application of pasture and/or crop treatment chemicals (incl contractors)	
	Disposal of chemicals	
	Identification and traceability of treated pastures and/or crops	
	Manage withholding periods	
6 Feedstuffs	Manage alternative feed sources	
	Selection of feed type	
	Purchase of feed	
	Receipt of feed	
	Identify and trace feed, storage of feed, treatment of feeds	
	Preparation of ration, distribution of feedstuff	
	Supplementation programme, feed disposal	
7 Water supply	Water source, water quality/contamination, storage	
	Distribution system	
8 Animal treatments	Growth promoters	
	Agricultural and veterinary chemicals/prescription drugs	Limited approval of chemicals for use on/in goats
	Parasite controls	
	Purchase of chemicals	
	Receipt of chemicals	
	Storage of chemicals, preparation of chemicals	
	Approval for use/off label use	Limited approval of chemicals for use on/in goats
9 Livestock dispatch	Selection of transport method (rail, road, sea, stock route)	
	Selection of transporter	
	Holding, loading and transhipment	
	Completion of movement documentation	

Adapted from Horchner *et al.*, copyright 2006, with permission of Elsevier.

Table 4.37 Hazard identification step for the meat and livestock industry overall.

Hazard	Hazard? (Y/N)	Food safety market access issue? (Y/N)	Animals primary source (A = animal) (P = processing)	Effective measures on-farm? (Y/N)	Effectively controlled elsewhere? (Y/N)	Consider further in on-farm food safety scheme? (Y/N)
1. Biological						
1.1 Microbiological						
Campylobacter jejuni/coli	Y	N	A	N = potential controls but not yet validated	Y = processing controls	N
Clostridium perfringens	Y	N	P/A	N	Y = processing controls	N
Indicator bacteria, e.g. Generic *E. coli*; TVC; Coliforms	N	Y	A/P	Y = valid and practical measures established; clean livestock	Y = processing controls in place but made easier if clean livestock	Y
E. coli (EHEC)	Y	Y	A	N = potential controls identified but not yet validated	Y = processing controls in place to reduce incidence and monitor	N
Listeria monocytogenes	Y	N	P	N	Y = processing controls	N
Salmonella	Y	Y (Sweden)	A	N? = feed type, animal type, transport and time of feed links contribute but practicality of on-farm control is questionable	Y = processing controls in place but reduce incidence if pre-slaughter hygiene measures adopted by producers	N
Staphylococcus aureus	Y	N	P	N	Y = processing controls in place	N
Yersinia enterocolitica	Y	N	A	N = potential controls but not yet validated	Y = processing controls in place	N
Aeromonas hydrophila	N	N	P/A	N	Y = general processing controls in place	N
Antimicrobial resistant bacteria	Y	N	A	Y = suspected causes during animal treatments but links not fully known	N	N
Mycobacterium paratuberculosis (BJD, OJD)	N	N Economic production issue	A	Y = BJD/OJD Market Access Programmes	N	N
Bacillus cereus	Y	N	A/P	N	Y = general processing controls in place	N
Toxoplasma gondii	Y	N	A	N	N	N
Bacillus anthracis	Y (milk)	Y	A	Y = vaccination at high-risk times	N	N
BSE	Y	Y	A	Y = prohibition on feeding meat and bone meal	N	Y
1.2 Macrobiological						
Tuberculosis	Y for milk only	Y	A	Y	Y = inspection, TFAP	N

CLA	N	N	A	Y = vaccination	Y = inspection	N
Gross abnormalities	N	Y	A	N	Y = inspection	N
Beef measles	Y	Y	A	Y = valid, practical, simple preventive measures exist	Y = inspection to detect but more effectively controlled on-farm	Y
Sheep measles	N	N = not public health problem, economic issue only	A	Y = valid, practical, simple and inexpensive controls exist	Y = inspection	N
Hydatids	N = as human infection is not from consumption of meat	N = not food safety problem, economic issue only	A	Y = valid, practical, simple and inexpensive controls exist	Y = inspection	N
Sarcocystis	N	N = not public health problem, economic issue only	A	Y = valid, practical, simple and inexpensive controls exist	Y = inspection	N
Plant-associated toxins	N	N	A	N	N	N
Corynetoxins	N	Y (hay)	A	Y = stock feed controls	Y = feed programmes and codes of practice	N
Pyrrolizidine alkaloids	Y	N	No = stock feeds only	Y = stock feed controls	Y = feed programmes and codes of practice	N
Mycotoxins	Y	Y	No = stock feeds only	Y = stock feed controls	Y = feed programmes and codes of practice	N
2. Physical						
Broken needles	Y	Y	A	Y = good husbandry practices	Y = inspection may detect; some product subject to metal detection but more efficient to control on-farm	Y
Lead shot	N	N	A	Y = good husbandry practices	Y = inspection may detect; some product subject to metal detection but more efficient to control on-farm	N
3. Chemical						
Hormones	Nb	Y	A	Y = safe use and ID of treated animals. Restricted supply to specified markets	N	Y
Organochlorines	Nb	Y	A	Y = controlled use of Ag and vet chemicals	N	Y
Organophosphates	N	Y	A	Y as above	N	Y
Macrolytic lactones	N	Y	A	Y as above	N	Y
Synthetic pyrethroids	N	Y	A	Y as above	N	Y
Benzoyl ureas	N	Y	A	Y as above	N	Y
Antimicrobial residues	Y	Y	A	Y as above	N	

Source: Meat and Livestock Australia, 2003a; 2003b.

Table 4.38 Decisions taken in the determination of critical control points (CCP) and PRPs for on-farm food safety.

Process steps		Activities associated with this step	Hazard	Q1	Q2	Q3	Q4	Q5	CCP or PRP
1	Feedstuffs	Purchase of feed	Biological: BSE	Y	Y	N	Y	Y	PRP
			Chemical	Y	Y	N	Y	Y	PRP
		Treatment of feeds	Chemical	Y	Y	N	Y	Y	PRP
		Ration preparation	Biological: BSE	Y	Y	N	Y	N	CCP
2	Animal Treatments	Agricultural and veterinary Chemicals/prescription drugs	Chemical	Y	Y	N	Y	Y	PRP
		Parasite controls	Chemical	Y	Y	N	Y	Y	PRP
		Approval for use/off label use	Chemical	Y	Y	N	Y	Y	PRP
		Application of chemicals (incl contractors)	Biological: Biological hazards (abscess)	Y	Y	N	Y	Y	PRP
			Chemical	Y	Y	N	Y	Y	PRP
			Physical: Physical hazards (metal)	Y	Y	N	Y	Y	PRP
		Identification and traceability of treated animals	Chemical: Residue status	Y	Y	N	Y	Y	PRP
3	Preparation for transport	Assessment and selection	Biological: Beef measles status	Y	Y	N	Y	N	CCP
			Chemical: Residue status	Y	Y	N	Y	N	CCP
		Assembly and drafting	Biological: Indicator bacteria, including *E. coli*	Y	Y	N	Y	Y	PRP
			Biological: *Salmonella*	Y	Y	N	Y	Y	PRP
			Biological: Micro-organisms of public health concern	Y	Y	N	Y	Y	PRP

Adapted from MLA (2003).

procedures before slaughter to minimise contamination of carcasses with microbiological hazards (Bach *et al.*, 2004) is underscored by recent results on *E. coli* O157 carriage at slaughter (Fegan *et al.*, 2004).

There appears to be limited value in the application of preventive disease control programmes to reduce the presence of gross carcass abnormalities at slaughter (Edwards *et al.*, 1999; Green *et al.*, 1997). In addition, most pathogen-specific abnormalities (Edwards *et al.*, 1999) are caused by agents which are not foodborne hazards for humans. Additionally, the occurrence of foodborne hazards in non-specific gross abnormalities such as abscesses and arthritis is uncertain but can be predicted to be very low (Pointon *et al.*, 2000). Nevertheless, animal health programmes are essential for the well-being and welfare of livestock.

However, apart from the occasional animal condition caused by an agent which may subsequently be foodborne zoonoses (e.g. Beef Measles), disease prevention programmes have minimal impact on reducing gross abnormalities that are likely to contain low levels of foodborne hazards, and as such fail to meet the criteria for a CCP. In relation to *Salmonella* spp. that occur widely in lymph nodes of normal cattle (Moo *et al.*, 1980), effective control measures are not validated on farm and processing controls elsewhere (e.g. knife sterilisation) are designed to minimise contamination that may arise.

4.23.7 Trichinella in pigs

The prevention of human trichinellosis by proper meat inspection is a classic example of successful veterinary public health measures. The microscopic tests which have been used for more than a century to test pigs for the parasite were intended to prevent human

disease. However, the value of these relatively insensitive direct detection methods, including trichinoscopy and pooled sample digestion, was debated as soon as more sensitive indirect (serological) methods became available. Trichinella-free pig farming is a feasible option for controlling this zoonosis, even in endemic areas.

4.23.8 L. monocytogenes in RTE meats

In the USA a risk assessment was undertaken to provide a risk ranking of various RTE foods, to determine which foods provided a greater risk to human health than others (HHS/USDA, 2003). RTE food categories used in the assessment were selected based on their potential for *L. monocytogenes* contamination, history of causing listeriosis, and availability of food contamination and consumption data. Food categories included meats (frankfurters, dry/semi-dry fermented sausages, delicatessen meats and pate), seafood, dairy, fruits and vegetables and delicatessen salads. In the USA, deli meats, frankfurters (not reheated) and pate and meat spreads pose a much greater risk (about 1 case of listeriosis per 10^7 servings is predicted) than hard cheeses, cultured milk products and processed cheeses, where the predicted level of illness is approximately 1 case of listeriosis per 10^{14} servings. The main reason for this is that the former group of foods supports the growth of *L. monocytogenes* to high numbers while the latter group does not.

L. monocytogenes may be found on ready-to-eat (RTE) meats, posing a public health risk. To minimise the public health impact, an appropriate level of protection (ALOP) can be established for a population with respect to *L. monocytogenes*, and ideally should be based on a scientific assessment of the risk, as well as societal and economic factors. Food safety systems can be based on meeting the ALOP. Food safety objectives (FSO) provide a link between the ALOP and performance objectives that are established to control a foodborne hazard. An FSO can be used as a risk-management tool for *L. monocytogenes* in RTE meats, as the FSO establishes the stringency of the measures being used to control the hazard, by specifying the frequency and/or cell number of the pathogen in the food that should not be exceeded at the time of consumption. Typically, this requires setting performance objectives or performance criteria at an earlier point in the food chain (Walls, 2006), to ensure that the product will meet the FSO. Establishing an FSO requires an assessment of the risk of the hazard to the population of interest. Risk-management strategies such as use of HACCP systems and GMPs can then be used to ensure that the FSO is met.

4.24 HAMBURGER PATTIES

Hamburger patties are mostly produced in large batches at meat-processing plants rather than in small batches at the cutting facilities of retail outlets. Large-scale patty manufacture commonly involves the grinding of manufacturing beef from two or more sources for each batch. Chilled product is usually obtained in bulk containers which hold 450 kg of meat, from a few plants which are geographically convenient to the manufacturing plant. Frozen product is usually obtained in 25 kg boxes, from overseas as well as from more local suppliers in Canada (Gill *et al.*, 1997).

Typically, production of a batch involves the grinding of meat from two or three bulk containers of chilled meat of different fat contents. Low-fat, tempered frozen product may be substituted for low-fat, chilled meat. The ground meat is blended in a mixing vat, with CO_2 snow being added as required to maintain a product temperature of about 0°C. The blend is tested for its fat content, which is adjusted if necessary, before the batch is fed to patty forming equipment. The patties may be packaged as chilled product or as frozen product after cryogenic freezing.

When patties are prepared in a central cutting facility which supplies a group of retail outlets, the manufacturing beef may be supplemented with trimmings from retail-ready cuts and with meat which has been removed from retail display as a result of deterioration of its appearance.

The hygienic conditions of the hamburger patties collected from three patty manufacturing plants and six retail outlets were examined by Gill *et al.* (1997). At each manufacturing plant a sample from newly formed, chilled patties and one from frozen patties were collected from each of 25 batches of patties selected at random. At three, two or one retail outlet, respectively, 25 samples from frozen, chilled or both frozen and chilled patties were collected at random. Each sample consisted of 30 g of meat obtained from five or six patties. Total aerobic, coliforms and *E. coli* counts per gram were enumerated for each sample. The findings indicate that the general hygienic condition of hamburgers patties could be improved by their being manufactured only from beef of superior hygienic quality and by the better management of chilled patties at retail outlets.

This is an obvious CCP with an equally obvious practical control procedure. If the incoming material

is controlled for microbiological contamination, e.g. standard set for the limit of cfu/g, then the risk of subsequent development of microbial growth and cross-contamination within the plant is reduced. In order to assist and support such a programme ingredients should be purchased from suppliers who are applying a HACCP programme and are being audited regularly to ensure their compliance with the product specifications (Mortimore and Wallace, 1995). In order to retard microbiological growth, the temperature of raw materials at delivery should be 1–4°C, apart from meat patties, which are usually frozen at a temperature below −18°C. All packages should be undamaged and secure in order to minimise the presence of foreign matter (Alli, 1992).

Determining the expected shelf life of the incoming ingredients and discarding the materials that have exceeded their shelf life can control abuse of storage holding time. Temperature abuse can be avoided by maintaining the temperature of the ingredients at 1–4°C, apart from meat patties that should be frozen (Sandrou and Arvanitoyannis, 1999). During preparation cross-contamination of the materials can occur by microbial foreign and chemical bodies (Mortimore and Wallace, 1995). The use of different coloured uniforms and physical barriers can help enforce traffic controls. The equipment and food contact surfaces should be cleaned, rinsed and sanitised frequently (Sperber, 1982).

After preparation, hamburgers are placed in buns and garnishes are added. Hazards are associated with the persons who assemble the sandwiches and with the garnishes. To control these problems, training of personnel in good hygienic practices and careful handling of garnishes are essential (ICMSF, 1988). Hamburgers should be wrapped to avoid cross-contamination by foreign material and to keep the product undamaged and secure. The flow diagram of hamburger preparation is shown in Fig. 4.13 and the determination of CCPs according to HACCP, determination of PRP according to ISO 22000 and the comparative presentation of CCPs according to HACCP and ISO 22000 in conjunction with PRPs for hamburger preparation are given in Tables 4.39–4.41, respectively. The flow diagram of minced meat is given in Fig. 4.14. The determination of CCPs for minced meat is given in Table 4.42.

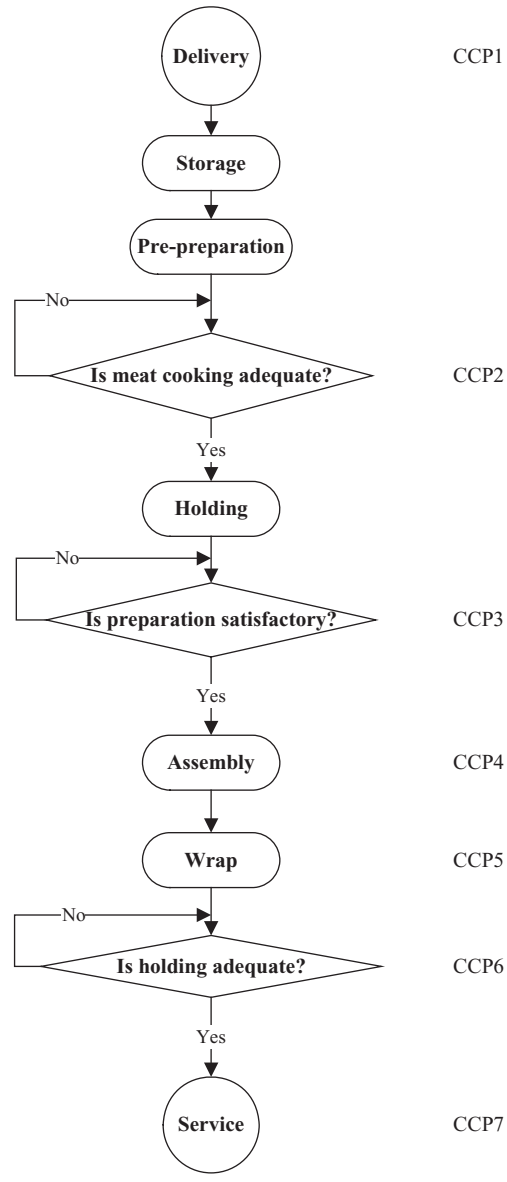

Fig. 4.13 Hamburger preparation in a fast food restaurant.

4.25 SKINNING OPERATION IN THE BEEF CARCASS DRESSING PROCESS

A major potential source of microbial contamination is the residual faecal matter which is present and may be released during processes involving the hindquarters of animals. Studies have been carried out into procedures which potentially reduce this type of contamination.

The hindquarters skinning operations in a commercial beef carcass dressing process were modified, and for short trial periods reorganised for the purpose of reducing the numbers of bacteria deposited on the carcasses (Gill and McGinnis, 1999).

Table 4.39 Determination of CCPs to HACCP for hamburger preparation.

A/A CCP	Processing step	Q1	Q2	Q3	Q4	CCP
1	Delivery	Yes	Yes	—	—	1
2	Storage	Yes	No	Yes	Yes	—
3	Preparation	Yes	No	Yes	Yes	—
4	Cooking (meat)	Yes	Yes	—	—	2
5	Holding meat	Yes	No	Yes	No	3
6	Assembling	Yes	No	Yes	No	4
7	Wrapping	Yes	No	Yes	No	5
8	Holding	Yes	No	Yes	No	6
9	Servicing	Yes	No	Yes	No	7

The carcass dressing process at a plant which slaughters approximately 1500 cattle during an eight hour period was examined. The process included eight hindquarters skinning operations.

1. Open skin of crotch, belly and left hock.
2. Skin left hock and medial surface of left leg. Remove left hoof.
3. Skin left rump, working from anterior to posterior or vice versa.
4. Gambrel left leg. Unchain right leg.
5. Skin right hock and medial surface of right leg. Remove right hoof.
6. Skin right rump, working from anterior to posterior or vice versa.
7. Raise and gambrel right leg.
8. Skin flanks, with freeing of the skin over the backbone.

The modification was that on agreed days, for periods of about one hour each day, hindquarters skinning was reorganised to ensure that each worker performed only one operation during that time.

Table 4.40 Determination of PRP according to ISO 22000 for hamburger preparation.

A/A CCP	Processing step	Q1	Q2	Q3	Q4	PRP?
1	Delivery	Yes	Yes	No	Yes	Yes
2	Storage	Yes	Yes	No	Yes	Yes
3	Preparation	Yes	Yes	No	Yes	Yes
4	Cooking (meat)	Yes	Yes	No	No	No
5	Holding meat	Yes	Yes	No	No	No
6	Assembling	Yes	Yes	No	Yes	Yes
7	Wrapping	Yes	Yes	No	Yes	Yes
8	Holding	Yes	Yes	No	No	No
9	Servicing	Yes	Yes	No	Yes	Yes

Table 4.41 Comparative presentation of CCPs according to HACCP and ISO 22000 in conjunction with PRPs for hamburger preparation.

Processing step	HACCP CCPs	ISO 22000 PRP?	ISO 22000 CCPs
Delivery	1	Yes	—
Storage	—	Yes	—
Preparation	—	Yes	—
Cooking (meat)	2	No	1
Holding meat	3	No	2
Assembling	4	Yes	—
Wrapping	5	Yes	—
Holding	6	No	3
Servicing	7	Yes	—

During performance of modified or reorganised operations, samples were obtained from randomly selected carcasses, by swabbing specified sites related to opening cuts, rump skinning or flank skinning operations, randomly selected sites along the lines of the opening cuts, randomly selected sites on the skinned hindquarters of carcasses, or randomly selected sites on carcass sides leaving the dressing process (Gill and McGinnis, 1999). For each form of the hindquarters skinning operations, a set of 25 samples of each type was collected, with a single sample being obtained from each selected carcass or side. Aerobic counts, coliforms and *E. coli* were enumerated in each sample, and a log mean value was estimated for each set of 25 counts on the assumption of a log normal distribution of the counts. The data indicated that the log numbers of total aerobes, coliforms and *E. coli* that were deposited on carcasses during the modified hindquarters skinning operations were generally about 0.5, 1.0 and 1.0 log unit less, respectively, than the log numbers that had been deposited on the carcasses during the unmodified operations.

Reorganisation of the modified operations gave further small but consistent reductions in the numbers of bacteria. It, therefore, appears that changes to dressing procedures which are guided by appropriate microbiological data can produce consistent reductions in the microbiological contamination of carcasses.

4.26 ORGANIC ACIDS AS MEAT DECONTAMINANTS

A considerable literature reports the antibacterial efficacy of dilute solutions of organic acids (lactic, acetic). With carcasses an overall reduction in surface contaminants of 1.5 log cycles can be expected. Carcass

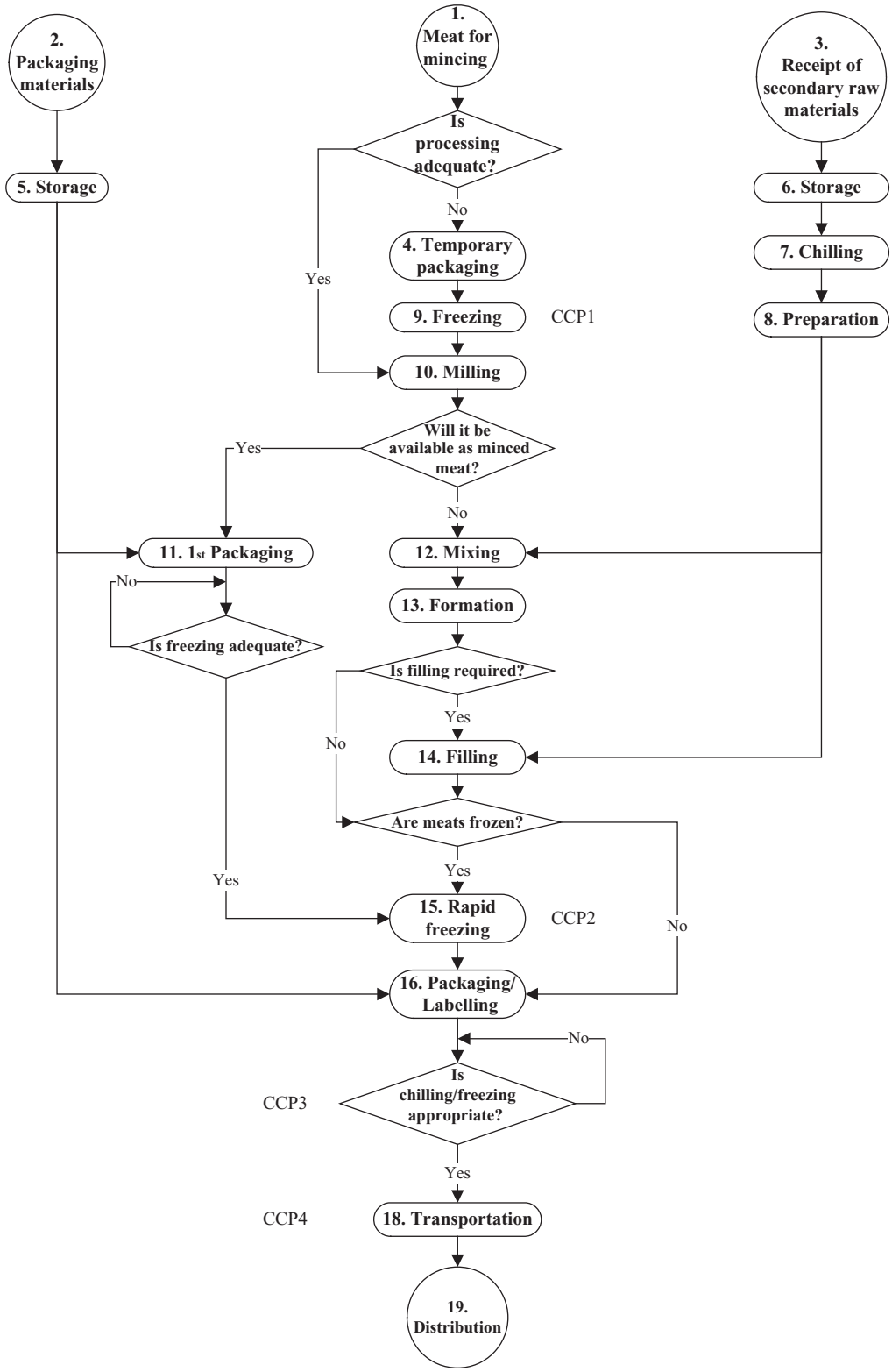

Fig. 4.14 Flow diagram of minced meat production.

Table 4.42 Determination of critical control points for minced meat.

A/A CCP	Step	Do control measure(s) exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of a hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable levels?	Will a subsequent step eliminate identified hazards or reduce likely occurrence to acceptable levels?	CCP
1	Receiving of raw materials	Yes	No	No		cp
2	Storage of raw materials	Yes	No	No		cp
3	Chilling/freezing	Yes	Yes			CCP1
4	Milling	Yes	No	No		cp
5	1st Packaging	Yes	No	No		cp
6	Mixing	Yes	No	No		cp
7	Formation	Yes	No	No		cp
8	Filling	Yes	No	No		cp
9	Rapid freezing	Yes	Yes			CCP2
10	Packaging/labelling	Yes	No	No		cp
11	Chilling/freezing	Yes	Yes			CCP3
12	Distribution	Yes	Yes			CCP4

decontamination may not improve the safety of the resultant meat, but laboratory trials confirm that acid decontamination of subprimal and retail cuts is more efficacious. An advantage over many other intervention strategies is that residual antimicrobial activity is demonstrable over extended periods of storage. Studies by Smulders and Greer (1998) have also shown that some meatborne pathogens are particularly sensitive to organic acids (i.e. *Y. enterocolitica*) while others are resistant (i.e. *E. coli* O157:H7). Dilute solutions of organic acids (1–3%) are generally without effect on the desirable sensory properties of meat when used as a carcass decontaminant. However, dependent on treatment conditions, lactic and acetic acid can produce adverse sensory changes when applied directly to meat cuts, with irreversible changes in appearance being a frequent occurrence. It is speculated that organic acid decontamination will be implemented in American abattoirs in an effort to meet specified performance standards for pathogen reduction as part of an overall HACCP programme. In contrast, the EU advocates that strictly controlled processing hygiene is sufficient to ensure the safety of the product. Additional research is necessary to establish a set of treatment conditions that may permit a practicable reduction in bacterial contamination throughout the processing chain with a measurable effect on safety and storage life, without imposing any change in sensory properties. It will also be necessary to develop standard, objective measures to assess HACCP and the efficacy of decontamination procedures.

4.26.1 Control of hygiene in abattoirs

The main sources of contamination for red meat are organisms in the alimentary tract of the animal or on the hide, skin or fleece. Production of clean meat depends largely on the care with which the carcass is eviscerated and dressed. Despite this, much of the emphasis in EU legislation governing slaughter and dressing of meat animals has focused on the design and layout of buildings and on the materials to be used for working surfaces, walls and equipment. These aspects are important in creating an environment in which hygienic practices can be developed and applied, and in fostering the correct attitude to hygiene among abattoir personnel. However, the environment in which the animal is handled is not usually the main factor in controlling microbial contamination of carcasses. For example, Hudson *et al.* (1983) studied the microbiological condition of beef carcasses at three UK abattoirs, only one of which was EU approved for export purposes. Of the three, the last-mentioned produced the most heavily contaminated carcasses and the problem was clearly an operational one. Carcasses were too crowded on the line because of the high throughput, while excessive use of water during dressing led to conditions that favoured microbial growth on carcass surfaces during

chilling (Mead, 1994). These stages in the slaughter process which have the greatest effect on carcass contamination are well known.

On beef and sheep lines, the manner in which the hide or fleece is removed is critical, as is removal of the head and hooves – all parts of the animal that carry large numbers of micro-organisms. For all meat animals, evisceration is an important stage because, if done carelessly, considerable spread of intestinal organisms can result.

With pigs, other important stages are scalding, scraping and 'polishing' of carcasses.

In the abattoir, relatively simple measures can be used to reduce carcass contamination or to limit the spread of any foodborne pathogens. Such measures would include use of a freshly decontaminated stick-knife for each animal and, in the case of pigs, ensuring that scald water is maintained at 60°C or above, and frequently replenished.

Other controls could include closing-off the anus in a plastic bag and clipping-shut the oesophagus to prevent outflow of rumen fluid in, for example, sheep. However, these particular measures are not universally applied or accepted by the industry (Mead, 1994).

4.27 CONCLUSIONS

Individual operations for the production of different meat products may vary; however, it should be clear from the evidence presented in this chapter that the application of HACCP principles and implementation of relatively simple modifications at CCP are beneficial practical terms for the meat product producer. The reduction of microbial contamination reduces risks, limits product recalls and enhances customer satisfaction.

Establishments must determine whether *E. coli* O157:H7 is a hazard reasonably likely to occur by examining the adequacy of current controls, as well as whether their raw beef products tested positive for the pathogen in either FSIS (FSIS reference method includes 20-hour enrichment in a broth medium, an immunoassay screening test, and confirmation of positive results by immunomagnetic separation and selective plating) or industry testing. In addition, all establishments are required to conduct on-going verification activities to ensure that their CCPs are adequately addressing *E. coli* O157:H7 (http://haccpalliance.org/alliance/ec0920.pdf). Combined FSIS data for 1998–2002 period showed that *Salmonella* prevalence in all meat products decreased to levels below the baseline prevalence estimates determined prior to HACCP implementation. The data indicated that cows and bulls average 2.2% under HACCP compared to 2.7% prior HACCP and ground beef averages 3.2% compared to 7.5% (Rawson, 2003).

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5
Poultry

Ioannis S. Arvanitoyannis and Theodoros H. Varzakas

5.1 INTRODUCTION

Chickens, turkeys, ducks and other types of poultry are all produced using similar methods. Recommendations on measures to improve the hygiene of poultry processing were published by a UK government/industry working group on meat hygiene (CDC, 2007). The following broad points were recommended:

1. Poultry flocks: measures should be put in place to ensure the health of the flock and where there is evidence of pathogen contamination of a flock, additional systems and measures to minimise cross-contamination should be applied at the slaughterhouse.
2. HACCP (Hazard Analysis of Critical Control Point): the application of HACCP to the slaughtering process in the production of poultry products was recommended. A framework is given by the group as a starting point for the development of a HACCP system for poultry processing.
3. *Salmonella* testing: flocks should be tested 2–3 weeks before slaughter to enable the known contaminated flocks to be slaughtered at the end of the production day and after those flocks that have no signs of *Salmonella* infection.
4. Process treatments: the group endorsed the use of processes or treatments to reduce contamination of the final product provided there is a clear benefit to public health and that such treatments are not put in place as an alternative to good hygiene practice (GHP).
5. Training: the group recommended the effective training of slaughterhouse personnel and described a set of training targets (Bell and Kyriakides, 2002).

Salmonellas are the most commonly reported infection, the relative importance of other agents varied (Havas, 1995). The HACCP concept provides a systematic approach for improving the preparation and handling of poultry products, so as to reduce significantly the incidences of foodborne illness (Tompkin, 1990).

The problem of human salmonellosis is due to the synergistic action of various factors. Trends are driven by both intrinsic factors related to the microbiological quality of the food, standards of preparation and extrinsic factors, such as ambient temperatures which amplify the intrinsic effects. Many of these factors may be amenable to preventive activities, including programmes targeted to educate the consumer in safe food handling (Stockett, 1995). *Salmonella* infection is spread among poultry through the use of contaminated feed and the incidence tends to reach a peak where intensive stock raising is practised (Crossland, 1997). The determination of the principal routes of infection of poultry has made possible the demonstration of control strategies. The acquisition of infection-free breeding flocks by companies in the UK broiler industry has brought about a marked reduction in the prevalence of broiler carcasses contaminated with *Salmonella enteritidis*. In Scandinavia, hygiene barriers and boot dipping in broiler houses have substantially reduced the carriage rates of *Campylobacter jejuni*, which is usually acquired in broiler chickens from the external environment (Humphrey, 1996).

C. jejuni and *Escherichia coli* are found in the intestines of farm and domestic animals, in the intestine of poultry and in farm wastes. A strong relationship has been identified between poultry and food poisoning due to *Campylobacter*, and since there is some evidence that illness is caused by the ingestion of a small number of *Campylobacter*, contaminated chicken

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carcasses may act as vectors carrying *Campylobacter* into the kitchen (Shapton and Shapton, 1994).

In the UK, the highest level of *Salmonella* infections was in 1997 when the number of reports exceeded 32,000, but it has been well over 20,000 per year since 1988. In recent years, these figures have been decreasing as a result of public health and industry measures to control the organism, particularly in raw foods such as eggs and poultry (Wheeler *et al*., 1999).

Microbiological surveys of cooked poultry meat have been carried out by a number of workers and results reveal varying frequencies of *Listeria monocytogenes* contamination in this product. There is no question that in circumstances where a particular effort has been made to improve control of *L. monocytogenes*, the incidence of the organism in the targeted product groups has decreased (Bell and Kyriakides, 2005).

Stress in poultry is accompanied by a series of symptoms. The increased corticosteroid levels in blood plasma and the occurrence of damage to the intestinal tract, heart and blood vessels are of major importance. Decreased shear strength of the intestinal tract may result in gut breakage during processing, which is responsible for further spreading of micro-organisms over carcasses and equipment (Bilgili, 1988). Moran and Bilgiri (1990) demonstrated that stressing chicken broilers, under conditions simulating the practice of feed withdrawal and live haul, results in a faecal retention for up to 24 hours.

Bolder and Mulder (1983) reported an increase of *Salmonella* contamination in slaughtered broilers after transport. *Salmonella* serotypes after transport observed on slaughtered products originated from live birds, which indicates intestinal origin. To interrupt microbial cycles in animal production, more attention should be paid to aspects of contamination in relation to husbandry, nutrition and processing, including conditions of loading and transport.

It is important to understand that HACCP systems do not use microbiological data to analyse products for pathogens. Instead, HACCP systems are designed to provide information on the degree of process control exercised by a food manufacturer with the objective of reducing or eliminating microbiological hazards (McNamara, 1996).

The condition of the poultry at slaughter, the spread of contamination during slaughter and processing, and the temperature, time and other conditions of storage and distribution are the main determinants of poultry quality (Upton, 1996). *Salmonella* infection is often spread amongst poultry through the use of contaminated feed and the incidence tends to be highest where intensive stock raising is practised. Problems with *Salmonella* can be exacerbated by stress and starvation during transport. Hygiene during slaughter and dressing together with prompt and adequate cooling are important (Brown, 1982; Cooper, 1994). Modified atmosphere packaging of raw chicken can substantially inhibit the aerobic spoilage biota while allowing pathogenic *Listeria mocytogenes* to grow (Wimpfheimer *et al*., 1990). *C. jejuni* is widely recognised as pathogenic for humans and it is frequently isolated from poultry (Franco, 1988). *Clostridium botulinum* spores are occasionally present and must be considered in the storage of poultry products (Lucke and Roberts, 1992).

Two elementary schools were served lunches that were cooked in the same kitchen. An outbreak of *E. coli* O157:H7 occurred at one school where the dishes that were prepared for the school were lukewarm and kept for 33 minutes at an average temperature of 45°C before serving. However, no outbreak occurred at the other school where dishes were hot and were kept for 60 minutes at an average temperature of 50°C before serving. In a series of experiments on the survival of *E. coli* O157:H7 in the liquid portion of similarly prepared food, the population of *E. coli* O157:H7 was reduced by 10^{-3} by heating at 50°C for 60 minutes and by only 10^{-1} by heating at 45°C for 40 minutes. Further, *E. coli* O157:H7 survived at 45°C for 40 minutes but not at 50°C for 60 minutes at pH 4.0 with a 4.0% salt concentration that was similar to that of the liquid part of the food. These results indicate that pH and salt concentration of cooked food markedly affect the survival of *E. coli* O157:H7 and help to explain the occurrence of the disease outbreak at only one of the schools (Hara-Kudo *et al*., 2005).

For kitchen managers, the clear critical control point (CCP) is the length of time for which food is stored at a specific temperature after cooking. The implementation of procedures which ensure that the food in systems such as that described is maintained at above 50°C for times no longer than 60 minutes.

Between 1995 and 2000, a prospective survey was undertaken to investigate the levels of contamination of raw retail chickens ($n = 1127$) with salmonella and campylobacter. The levels of contamination over the 6-year period were 11% (95% CI, 6.5%) for salmonella and 57% (95% CI, 9.5%) for campylobacter. *S. bredeney* (20%) and *S. enteritidis* (18%) were the dominant serovars. Although salmonella contamination was higher (7%), since 1998, it has declined to 6% (Wilson, 2002). Contamination ranged from 0 to 44% between different producers. There was no significant difference between producers contributing large and small numbers of samples, although some small producers had much poorer contamination rates than others. *S. bareilly*, *S. bredeney*, *S. enteritidis* and

Table 5.1 Examples of food-associated outbreaks of illness caused by micro-organisms.

Food	Country	Micro-organism	Incidence	Reference
Retail chicken	Portugal	*Salmonella*	48	ACMSF (1996)
Retail chicken	Denmark	*Salmonella*	51	ACMSF (1996)
Turkey	Netherlands	*Salmonella*	26	ACMSF (1996)
Domesticated duck	Netherlands	*Salmonella*	26	ACMSF (1996)
Wild duck	Netherlands	*Salmonella*	62	ACMSF (1996)
Raw chicken, frozen (1987)	UK	*Salmonella*	101	ACMSF (1996)
Raw chicken, frozen (1990)	UK	*Salmonella*	143	ACMSF (1996)
Raw chicken, frozen (1994)	UK	*Salmonella*	281	ACMSF (1996)
Raw chicken, chilled (1987)	UK	*Salmonella*	103	ACMSF (1996)
Raw chicken, chilled (1990)	UK	*Salmonella*	143	ACMSF (1996)
Raw chicken, chilled (1994)	UK	*Salmonella*	33	ACMSF (1996)
Cooked turkey meat	UK	*Salmonella*	9	Synnott *et al.* (1998)
Raw chicken portions	Malaysia	*Listeria monocytogenes*	19	Arumugaswamy *et al.* (1994)
Poultry – regular-cut chicken and skinless-boneless chicken	USA	*L. monocytogenes*	7	Amoril and Bhunia (1999)
Raw chicken	Ireland	*L. monocytogenes*	14	Soultos *et al.* (2003)
Poultry prepared meals	Spain	*L. monocytogenes*	16	De Simon and Ferrer (1998)
Delicatessen turkey meat	USA	*L. monocytogenes*	29 (7 deaths)	Hurd *et al.* (2000)
Precooked sliced turkey	USA	*L. monocytogenes*	16	Frye *et al.* (2002)
Potted duck paste	Scotland	*Clostridium botulinum*	8 (8 deaths)	Leighton (1923)
Retail fresh poultry	USA	*Escherichia coli*	4	Doyle and Schoeni (1987).
Retail raw chicken	Netherlands	*E. coli*	15	Heuvelink *et al.* (1996)

S. virchow showed associations with particular producers. *Campylobacter* contamination remains high. Contamination ranged from 47 to 81% between different producers (Wilson, 2002). The examples of food-associated outbreaks of illness caused by micro-organisms are given in Table 5.1.

5.2 IRRADIATION OF POULTRY

Irradiation is the only physical process rendering contaminated poultry relatively safe, i.e. sterile, but potentially contaminated with residual toxins, other than by heat treatment.

Irradiation is applied in poultry, meats and meat products. It could be a CCP because it has the ability to reduce the vegetative cells of pathogenic bacteria as well as parasites. It is a safe technology widely recognised by the Codex Alimentarius Commission. Today, 40 countries allow the use of irradiation in one or more products: 12 countries use it to control pathogens in poultry, 8 in meat and 13 in fish and seafood.

5.2.1 Applications in poultry

Irradiation is the most effective physical processing method used to remove *Salmonella* and *Campylobacter* from poultry. These bacteria might be present due to inappropriate cooking time and temperature, recontamination following cooking due to contact with dirty surfaces, hands or tools.

5.2.2 Critical irradiation limits

In irradiated foods, critical limits are the doses where removal of pathogenic bacteria or parasite control is

accomplished without other damage to the product. Irradiation in medium doses (3–7 kGy) destroys the vegetative cells of most pathogenic bacteria effectively. Parasites require even smaller doses (<1 kGy) than bacteria.

The Codex Alimentarius Commission considers an acceptable irradiation dose in foodstuffs up to 10 kGy, whereas WHO considers that an irradiation dose >10 kGy in foodstuffs is safe and nutritionally acceptable when foods are manufactured under GMPs.

The recently implemented HACCP-based inspection model project (HIMP) has been designed for processors of young poultry, market hogs and fed cattle (Goodwin and Shiptsova, 2002). Under this method, food safety and non-food safety defects are set to predetermined performance criteria. For young poultry, the HIMP method places a carcass inspector prior to the chiller and critical assessments are made of each carcass. Food Safety and Inspection Service (FSIS) inspector verification checks resulted in a 99.9% reduction in defects over traditional slaughter inspection. One major advantage of HIMP is that food safety risks are effectively minimised without increased costs of government inspection and with increased throughput and reduction in plant downtime (Goodwin and Shiptsova, 2002).

5.3 MICRO-ORGANISMS

The *L. monocytogenes* surveillance programme has also shown an increase in the incidence of these micro-organisms in meat products, especially poultry (unpublished data). It is thus possible that some of the sporadic cases of listeriosis observed in Italy, for which the vehicle of infection was not identified, may have been associated with the consumption of foods of animal origin.

Pulsed-field gel electrophoresis (PFGE) was used to type 90 strains of *L. monocytogenes* isolated from clinical cases and from meat products in Italy in the period 1987–1995 (Gianfranceschi *et al.*, 2002). The objective of this retrospective study was to compare the genetic profiles to determine the existence of predominant clones and to evaluate their association with the sporadic cases of listeriosis reported in recent years in Italy. A total of 32 distinct PFGE types were identified: PFGE types 1 and 9 were identified both for strains isolated from clinical samples and those isolated from food. The use of the PFGE molecular method in surveillance projects and epidemiological investigations could contribute to better understanding of microbial populations and could also be useful, as part of the HACCP programme, in conducting controls along different points of the food production line.

5.4 DETECTION

Two rapid methods for *Salmonella* detection, Vidas-ICS and modified semi-solid Rappaport–Vassiliadis (MSRV) were evaluated using contaminated poultry meat (De Medici *et al.*, 1998). The sensitivity and specificity of the methods were investigated on field samples and on artificially contaminated samples inoculated with mixtures of *Salmonella* and non-*Salmonella* competing strains. ICS-Vidas and MSRV yielded virtually identical results, in full agreement with the standard cultural method (SCM). The MSRV method showed better results with artificially contaminated samples, but was less sensitive than SCM when applied to field samples. The use of the MSRV and Vidas-ICS methods could be particularly advantageous in the application of HACCP.

Sumner *et al.* (2004) reported that their study had parallels with the findings of Schlosser *et al.* (2000) and Sarwari *et al.* (2001). Firstly, there was no great concurrence between the suite of serovars isolated most frequently from red meat and those most commonly associated with salmonellosis in Australia. Secondly, *S. sofia* was isolated from 50% of poultry samples and yet caused only 0.3% of salmonelloses, pointing to a very low ability to cause human illness.

In the case of poultry meat, however, phage types of *S. typhimurium* isolated from poultry were responsible for a significant proportion of salmonelloses, a situation which pertained both before and after regulatory change (Anonymous, 2001).

Prima facie data do not suggest a positive public health outcome associated with the inception of new meat and poultry hygiene standards and regulations. This could be due to regulatory changes not being effective, either because they have not been implemented or/and because their implementation has not been effective. One should also bear in mind that the poisoning incidents are the result of poor cooking processes in the home or at cooked food outlets and that the contamination occurs in these areas not exclusively in the processing plants. Processes in the poultry industry like immersion chilling of chickens can intermittently cause significant outbreaks of salmonellosis such as the *S. typhimurium* PT126 outbreaks of 2001 (Anonymous, 2001). These examples follow investigations of food poisoning incidents where the aetiology was ascertained.

5.5 CAMPYLOBACTER

A total of 825 samples of retail raw meats (chicken, turkey, pork and beef) were examined for the presence of *E. coli* and *Salmonella* serovars by Zhao *et al.* (2001) and 719 of these samples were also tested for *Campylobacter* spp.

The samples were randomly obtained from 59 stores of four supermarket chains during 107 sampling visits in the Greater Washington, DC, area from June 1999 to July 2000. The majority (70.7%) of chicken samples ($n = 184$) were contaminated with *Campylobacter*, and a large percentage of the stores visited (91%) had *Campylobacter*-contaminated chickens. Approximately 14% of the 172 turkey samples yielded *Campylobacter*, whereas fewer pork (1.7%) and beef (0.5%) samples were positive for this pathogen. Of the 212 chicken samples, 82 (38.7%) yielded *E. coli*, while 11.9% of the turkey samples were positive for *E. coli*.

However, only 25 (3.0%) of the retail meat samples tested were positive for *Salmonella*. Significant differences in the bacterial contamination rates were observed for the four supermarket chains. Raw retail meats are potential vehicles for transmitting foodborne diseases, and their findings stress the need for increased implementation of HACCP and consumer food safety education efforts.

From May to August 2004, 127 samples of chicken meat for sale on the retail market in Ankara were analysed for the prevalence of thermophilic *Campylobacter* spp. (Savaşçi and Özdemir, 2006). *Campylobacter* spp. was isolated from 83.4% of the samples analysed. *C. jejuni* was found in 74.8% of all samples. A total of 364 thermophilic *Campylobacter* strains were isolated and the species distribution among these strains was 70.1% *C. jejuni*, 21.1% *C. coli* and 8.6% *C. lari*. The results obtained from the study indicate that hygienic and technical compliance is needed in all stages of poultry processing to reduce contamination and to prevent a public health hazard. An integrated HACCP plan must be applied from the farm to the table for the prevention of *C. jejuni* infections.

5.6 POULTRY SLAUGHTERHOUSES

Poultry carcasses usually have very high levels of contamination on the skin. They can present micro-organisms that cause foodborne illness as well as food spoilage. There are a series of micro-organisms on the surface of the carcasses which can be analysed in order to indicate the microbiological quality, the level of hygiene in production and handling, and the correct maintenance of the cold chain (Sandrou and Arvanitoyannis, 1999). Furthermore, they can help to predict the products' shelf-life. The flow diagram of slaughter and dressing of chicken broilers is given in Fig. 5.1.

Three mechanisms exist for the attachment of bacteria to poultry carcasses (NACMSF, 1997). Retention occurs when carcasses come into contact with water containing bacteria. Entrapment takes place when exposed tissue surfaces (skin, collagenous connective tissue, layers of muscle) absorb water and begin to swell. Adhesion occurs when micro-organisms adhere to surface tissues. Only some strains of salmonellae are capable of adhesion. It appears certain that bacteria are firmly attached to carcasses before the start of processing and hence it is very difficult to eliminate these during processing.

5.6.1 Stunning and bleeding

After leaving the holding areas, the animals are located in a stunning or immobilisation area where they are rendered unconscious.

Scalding is a process by which the bird is subjected to moist heat for a short time to loosen hair and facilitate the removal of feathers. Immersion scalding uses a single or two-stage scalder (Hinton *et al.*, 2004). Soft scalds ($\leq 55^{\circ}$C) and hard scalds ($> 55^{\circ}$C) are used for up to three minutes. When birds are immersed in the scalding tank, some of the dirt, faecal material and other contaminants on the surface of the bird are removed and contaminate the scald water; hence, scalding could be a means of cross-contamination. The number and incidence of *Salmonella* and *Campylobacter* in raw poultry carcasses are greatly affected by the operating conditions of scalding and defeathering, evisceration, washing, skinning, deboning, portioning, chilling, decontaminating (irradiation) and freezing. In commercial scalding, the temperature is set in a range of 50–60°C for 2–2.5 minutes. One study found that increasing the scalding water temperature from 50 to 60°C reduced the number of C. *jejuni* and *S. typhimurium* by approximately 6 log CFU/mL (Yang *et al.*, 2001). In contrast, Humphrey (2004) found that hot water (up to 80°C) treatments were not much more effective in removing *Campylobacter* as compared to cold water. So, he suggested that heat treatment is not a significant control measure, particularly when chicken carcasses are to be sold whole.

Treatment of wash water has been found to be a potential processing control to reduce contamination. Alternatives are treatment with chlorine water, electrolysed water, trisodium phosphate, cetylpyridinum chloride, hydrogen peroxide etc. (Park *et al.*, 2002).

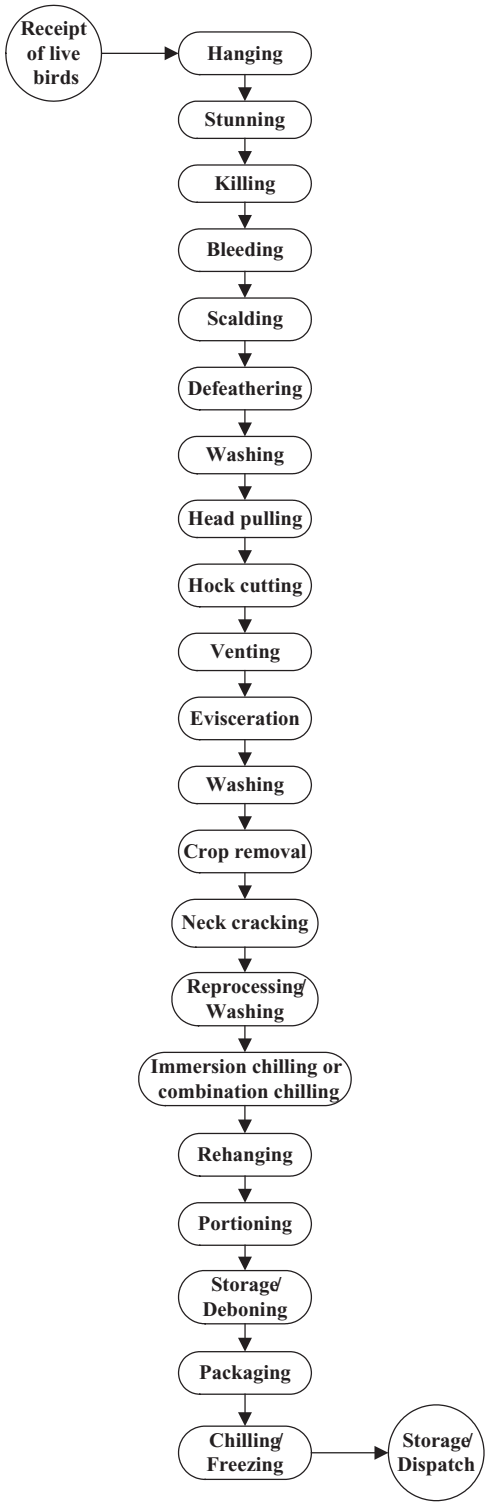

Fig. 5.1 Production of raw poultry meat.

The main objection to immersion scalding is the possible inspiration of contaminated scald water by the birds, with subsequent contamination of air sacs, lungs and other internal organs and edible tissues by pathogenic bacteria (Bailey *et al*., 1987). Hard scalding at about 58–60°C, followed by mechanical plucking, results in removal of the outer epidermal layer of the bird's skin. This cuticle-free skin of hard-scalded broilers serves as a more suitable substrate for bacterial attachment (Kim *et al*., 1993).

Counter-current scalders and multi-stage scalders have a greater impact on reducing the level of micro-organisms on the carcass (Bolder, 1998). Multi-tanks also reduce both the total aerobic and enterobacterial counts (Stals, 1996).

Defeathering is considered as a major site of cross-contamination for poultry carcasses by pathogens such as *Camplylobacter*, *Salmonella* and *E. coli*. (NACMSF, 1997). During the process, feathers, dirt and bacteria from carcasses are removed; however, formation of aerosols promotes the spread of bacteria, water and solid matter, thus contaminating other carcasses (Tinker *et al*., 1996). *Staphylococcus aureus* might also colonise the machinery by becoming associated with the rubber fingers used to remove the feathers. Despite all these bacteria and their possible presence, defeathering can result in a reduction on carcass contamination by 1000-fold (Hinton *et al*., 1996). Cross-contamination could be reduced if defeathering took place on a carousel.

The simplest physical decontamination method involves spraying with high pressure water or steam. Chemical decontaminants include acetic and lactic acids, and aqueous solutions of chlorine, hydrogen peroxide and inorganic acids.

Operator skills influence the levels of gut breakage in smaller plants. Moreover, full crops and intestinal tracts increase the risk of gut breakage; hence, feed should be withdrawn carefully prior to processing (Izat *et al*., 1989). In addition, shorter withdrawal periods may have more advantages in the reduction of bacteria in the crop and the caeca.

Finally, spray cleaning of carcasses during evisceration could prevent the occurrence of *Salmonella* and *Enterobacteriaceae*. Moreover, rinsing with chlorinated water could aid the minimisation of cross-contamination.

Proper cleaning and effective sanitation is an essential component of processing poultry, as it contributes significantly to the prevention of product contamination with micro-organisms that cause foodborne disease and spoilage. Rapid expansion of production volume, increased further processing and introduction of diverse ready-to-cook and ready-to-eat products,

Table 5.2 Determination of critical control points for poultry slaughtering.

A/A	Step	Do control measure(s) exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of a hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable levels?	Will a subsequent step eliminate identified hazards or reduce likely occurrence to an acceptable levels?	CCP
1	Receiving of live birds	Yes	No	No		cp
2	Hanging	Yes	No	No		cp
3	Stunning	Yes	No	No		cp
4	Killing	Yes	No	No		cp
5	Bleeding	Yes	No	No		cp
6	Scalding	Yes	No	No		cp
7	Defeathering	Yes	No	No		cp
8	Washing	Yes	No	No		cp
9	Head pulling	Yes	No	No		cp
10	Hock cutting	Yes	No	No		cp
11	Venting	Yes	No	No		cp
12	Evisceration	Yes	Yes			CCP1
13	Washing	Yes	No	No		cp
14	Crop removal	Yes	No	No		cp
15	Neck cracking	Yes	No	No		cp
16	Reprocessing	Yes	Yes			CCP2
17	Immersion chilling	Yes	Yes			CCP3
18	Rehanging	Yes	No	No		cp
19	Portioning	Yes	No	No		cp
20	Deboning	Yes	No	No		cp
21	Packaging	Yes	No	No		cp
22	Chilling/Freezing	Yes	No	No		cp
23	Storage/Dispatch	Yes	Yes			CCP4

sophistication of the processing equipment, implementation of HACCP and microbial finished-product standards, and, more importantly, expensive product recalls have necessitated greater control over the cleaning and sanitation process.

A sanitary process should effectively protect raw and/or cooked products from physical (i.e. metal, plastic, bone, packaging materials etc.), chemical (residues of cleaning and disinfection chemicals, lubricants, coolants etc.) and biological (foodborne pathogens and/or their toxins) hazards. In spite of this, many hazards continue to find their way into the processing environment and ultimately into the finished products. Micro-organisms are naturally introduced into the poultry processing environments in high numbers with the live birds and, when the conditions are suitable, form growth niches by actively multiplying within the system.

It is generally accepted that processing equipment should not be a direct or indirect source of microbial contamination. Many regulatory and advisory bodies have introduced hygienic design and processing guidelines. Bilgili (2006) reviewed the sanitary processing equipment design principles and equipment provided by the checklist by the American Meat Institute.

A plant designed, equipped, operated and maintained with internationally accepted hygienic and sanitary standards will produce safe and wholesome poultry products for the consumer.

Raw poultry are expected to carry pathogenic micro-organisms to a certain extent depending on their origin. Part of this contamination will continue to exist on slaughtered poultry carcasses and subsequently enter the processing plant when unprocessed raw materials are used as food ingredients (Sandrou and Arvanitoyannis, 1999).

Table 5.3 ISO 22000 Analysis worksheet for the determination of prerequisite programmes for poultry slaughtering.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Receiving of live birds	Yes	Yes	No	Yes	Yes
Hanging	Yes	Yes	No	Yes	Yes
Stunning	Yes	Yes	No	Yes	Yes
Killing	Yes	Yes	No	Yes	Yes
Bleeding	Yes	Yes	No	Yes	Yes
Scalding	Yes	Yes	No	Yes	Yes
Defeathering	Yes	Yes	No	Yes	Yes
Washing	Yes	Yes	No	Yes	Yes
Head pulling	Yes	Yes	No	Yes	Yes
Hock cutting	Yes	Yes	No	Yes	Yes
Venting	Yes	Yes	No	Yes	Yes
Evisceration	Yes	Yes	No	No	No
Washing	Yes	Yes	No	Yes	Yes
Crop removal	Yes	Yes	No	Yes	Yes
Neck cracking	Yes	Yes	No	Yes	Yes
Reprocessing	Yes	Yes	No	No	No
Immersion chilling	Yes	Yes	No	No	No
Rehanging	Yes	Yes	No	Yes	Yes
Portioning	Yes	Yes	No	Yes	Yes
Deboning	Yes	Yes	No	Yes	Yes
Packaging	Yes	Yes	No	Yes	Yes
Chilling/Freezing	Yes	Yes	No	Yes	Yes
Storage/Dispatch	Yes	Yes	No	No	No

The main emphasis of HACCP on slaughter operations is to minimise the potential for contamination of the finished raw products (Untermann, 1993). Current technology cannot assure a pathogen-free product (Baumgart, 1993), but it can minimise contamination from any slaughter operation (Goodfellow, 1995). Two fundamental concepts must be considered during the slaughtering process. The first one is related to the use of procedures which will minimise the degree of contamination on carcasses, such as training workers, providing adequate work space and time and a plant layout that favours microbial control and selecting equipment. For this purpose, cost-effective technology is needed (Mackey and Roberts, 1993). The second concept is to include procedures which can reduce or kill pathogens which inadvertently contaminate the carcass during slaughtering (Tompkin, 1994).

The crop is a potential source of *Salmonella* and *Campylobacter* contamination (Byrd *et al*., 1998). The increase in crop contamination has been attributed to the birds consuming litter and faecal droppings during the withdrawal period. A feed withdrawal period usually reduces gut breakage during evisceration.

Carcasses are usually spray washed after defeathering and evisceration with chlorinated water (concentration 10–100 ppm) to remove organic material and micro-organisms. Alternatively, trimming has been employed to remove faecal contamination from evisceration (Blankenship *et al*., 1993).

According to the Canadian standard, spray washing of carcasses takes place within 15 seconds after defeathering and after carcass transfer to reduce the presence of *Salmonella* and other bacteria to the skin (CFIA, 1999). However, *Salmonella* once attached to the carcass surface cannot be eliminated by rinsing or washing (Benedict *et al*., 1991).

Immersion chilling (immersion in ice or chilled water) or a combination of immersion chilling and wet air chilling (blast air chillers) are the methods used to reach an internal carcass temperature of 4°C within 24 hours of dressing. It takes approximately 50 minutes to achieve this temperature and the use of chlorinated water is essential. However, immersion chilling is an area of cross-contamination with *C. jejuni*, *Salmonella* and *C. perfringens* (Lillard, 1990). Chlorine can facilitate the hygienic operation of these systems. Chlorine

Table 5.4 Synoptical presentation of HACCP plan for poultry slaughtering.

CCP/ processing step	Critical limits	Monitoring CCPs	HACCP records	Verification	Corrective actions
1 P/B Evisceration	Zero visible faecal contamination after processing; equipment kept properly adjusted; no gut breakage due to improper equipment adjustment; range of 20–50 ppm chlorine	Visible check (at least once per hour of production); check chlorine at start up and every 2 hours using documented random sampling procedures to demonstrate control. Recording of results in appropriate Log. Equipment adjustment will be checked	Plant finished product standards form, antimicrobial sheet, equipment maintenance sheet, corrective action sheet	Once per shift, the QA supervisor will review the plant antimicrobial sheet and observe chlorine level testing. Twice per shift, maintenance supervisor will review equipment maintenance log	QA will reject or hold product until zero faecal tolerance is achieved. Equipment will be properly adjusted to assure zero contamination. All suspect product will be visually examined between evisceration and after final wash. Contaminated product will be rejected or reconditioned. Equipment maintenance and adjustments will be reviewed and compared to flock size and manufacturer's specs
2 P/B Reprocessing	Zero visible faecal contamination after re-processing; equipment kept properly adjusted; range of 20–50 ppm chlorine	Visible check on each lot (at least once per hour of production); check chlorine at start up and every 2 hours using documented random sampling procedures. Designated Quality Assurance employee will record results in appropriate Log	Reprocessing log (using plant finished product standards), antimicrobial log equipment, maintenance log, corrective action log	Once per shift, the QA supervisor will review the reprocessing log and antimicrobial log. Twice per shift, maintenance supervisor will review equipment maintenance log	QA will reject or hold product until zero faecal tolerance is achieved. Product will be reworked and reinspected by QA for faecal contamination. Any equipment adjustments will be made

(*Continues*)

Table 5.4 (Continued)

CCP/ processing step	Critical limits	Monitoring CCPs	HACCP records	Verification	Corrective actions
3 B Chilling (All Products)	Temperature of 5°C or less will be reached within 4 hours on all product. Chlorine dioxide level in chiller will be maintained at >20 ppm	Product temperature check monitored by QA technician at end of chilling procedure (every hour of production). Chill water will be tested for chlorine level every 2 hours by QA	Chilling log, carcass chiller, recording chart, neck/giblet chiller, thermometer, calibration log, corrective action log, antimicrobial log	Once per shift, the QA supervisor will review the chilling log, plant post-chill product standards form and antimicrobial log. Maintenance supervisor will verify accuracy of the carcass chiller and neck/giblet chiller temperature recording charts once per shift. QA will verify the chlorine concentration in the chiller once per week. QA will check all thermometers used for monitoring and verification for accuracy daily and calibrate	QA will reject or hold product depending on time, temperature and/or antimicrobial level deviation. QA will identify the cause of the deviation and prevent reoccurrence. Maintenance will check chiller circulation and water exchange rate and make adjustments as required. Any necessary repairs will be made. QA will monitor temperature and antimicrobial level in chiller every 2 hours until assured that process step is under control
4 B Finished Product Storage (Cold)	Finished product will not exceed 5°C	Maintenance personnel will check product temperature on carcasses every 2 hours	Chilling log thermometer, calibration log, corrective action log	Maintenance supervisor will verify the accuracy of the product temperature log once per shift. QA will check all thermometers used for monitoring and verification activities for accuracy daily and calibrate	If a deviation from a critical limit occurs, the following corrective actions will be taken: (1) The cause of the temperature exceeding 5°C will be identified and eliminated. (2) The CCP will be monitored hourly after the corrective action is taken to ensure that it is under control. (3) When the cause of the deviation is identified, measures will be taken to prevent it from recurring, e.g. if the cause is equipment failure, preventive maintenance programme will be reviewed and revised

Adapted from USDA, 1999a.
B, biological; P, physical.

Table 5.5 CCPs of HACCP and ISO 22000 for poultry slaughtering.

Process stage	CCP of HACCP	Prerequisite programme (ISO 22000)?	CCP of ISO 22000
Receiving of live birds	1	No	1
Hanging		Yes	
Stunning		Yes	
Killing		Yes	
Bleeding	2	No	
Scalding		Yes	
Defeathering		Yes	
Washing		Yes	
Head pulling		Yes	
Hock cutting		Yes	
Venting		Yes	
Evisceration	3	No	
Washing		Yes	
Crop removal		Yes	
Neck cracking		Yes	
Reprocessing	4	No	2
Immersion chilling	5	No	3
Rehanging		Yes	
Portioning		Yes	
Deboning		Yes	
Packaging		Yes	
Chilling/freezing	6	No	
Storage/dispatch	7	No	4

dioxide could also be added to reduce *Salmonella* in chilled water.

Alternatively, spray chilling and dry air chilling (hanging of birds) can be employed instead of immersion chilling to prevent cross-contamination. The disadvantage of dry air chilling is the dehydration of the carcass surface after it has been packed (Grey and Mead, 1986).

The average temperature of the washing stage is approximately 12–13°C and the carcasses enter the washing stage at a temperature of approximately 39°C and leave at approximately 37°C. This is a very important operation, since cleaning carcasses eliminates many micro-organisms (Gonzalez-Miret *et al*., 2006) before the air chilling stage.

Air chilling is the first stage of the clean zone and it is achieved thanks to a dynamic cooling tunnel. The carcasses are rapidly refrigerated by means of a cooling tunnel. The latter consists of a refrigeration vault, at a very low temperature (−6°C to +2°C), with a relative humidity of 69%. The process occurs in approximately 100 minutes. At the end of this step the carcasses are between 4 and 9°C, depending on their size. It avoids the growth of the non-psychrotrophic flora and it slows down the growth of the psychrotrophic flora.

It has been suggested that air chilling of the carcasses is more effective in eliminating the contamination than water chilling (Jacobs-Reitsma, 2000).

Freezing of the carcasses is another way of reducing the bacterial load. It was demonstrated in a study from Ireland that avoiding consumption of fresh chicken (eating only frozen chickens) reduced the cases of domestic campylobacteriosis by 72% (to 158 per 100,000 inhabitants; Takkinen and Ammon, 2003).

Irradiation can eliminate potentially pathogenic non-spore forming bacteria including *Salmonella* and *Campylobacter* from suspected food products like poultry without affecting the quality of the product (Farkas, 1998).

Slaughterhouses most frequently carry out total count, *Pseudomonas* and Enterobacteriaceae microbial analyses. The usefulness of such analyses can be assessed by means of univariate and multivariate statistical methods. Gonzalez-Miret *et al*. (2006) evaluated the use of these microbiological parameters for verification of the effect of the stages of washing with pressurised water and air chilling. This study shows that multivariate statistics are a valuable tool for checking which points and stages of the process must be controlled. It also demonstrated that the washing stage produces significant decreases in contamination (so it must be considered a CCP). The air chilling stage maintains the decrease in the contamination as the carcasses come out of the washing process. This is due to the control of temperature within specified limits. The chiller air temperature would be considered a CCP in a HACCP system.

During portioning and deboning the major microbiological dangers are the redistribution of pathogenic bacteria present on the incoming carcasses and the transfer of micro-organisms from the work environment (MAF, 2000).

GMP cleaning and sanitation methods should be employed on cutting boards, deboning tables, conveyors, knives, hands and personnel clothes (IFST GMP 5, 2007). Contamination of products with *L. monocytogenes* during portioning and deboning is also feasible. Bone particles greater than 20 mm could be a food safety hazard and could cause injury to consumers.

Finally, freezing below −8°C usually does not support microbial growth. However, *Salmonella*, *Staphylococci* and *C. perfringens* spores might survive during freezing. The main method for destruction of vegetative pathogens in poultry is cooking or heating to a minimum internal temperature of 71°C for 2 minutes to reduce *Salmonella* and *L. monocytogenes* (UK Department of Health, 1989; USDA FSIS Code of Federal Regulations, 1999b).

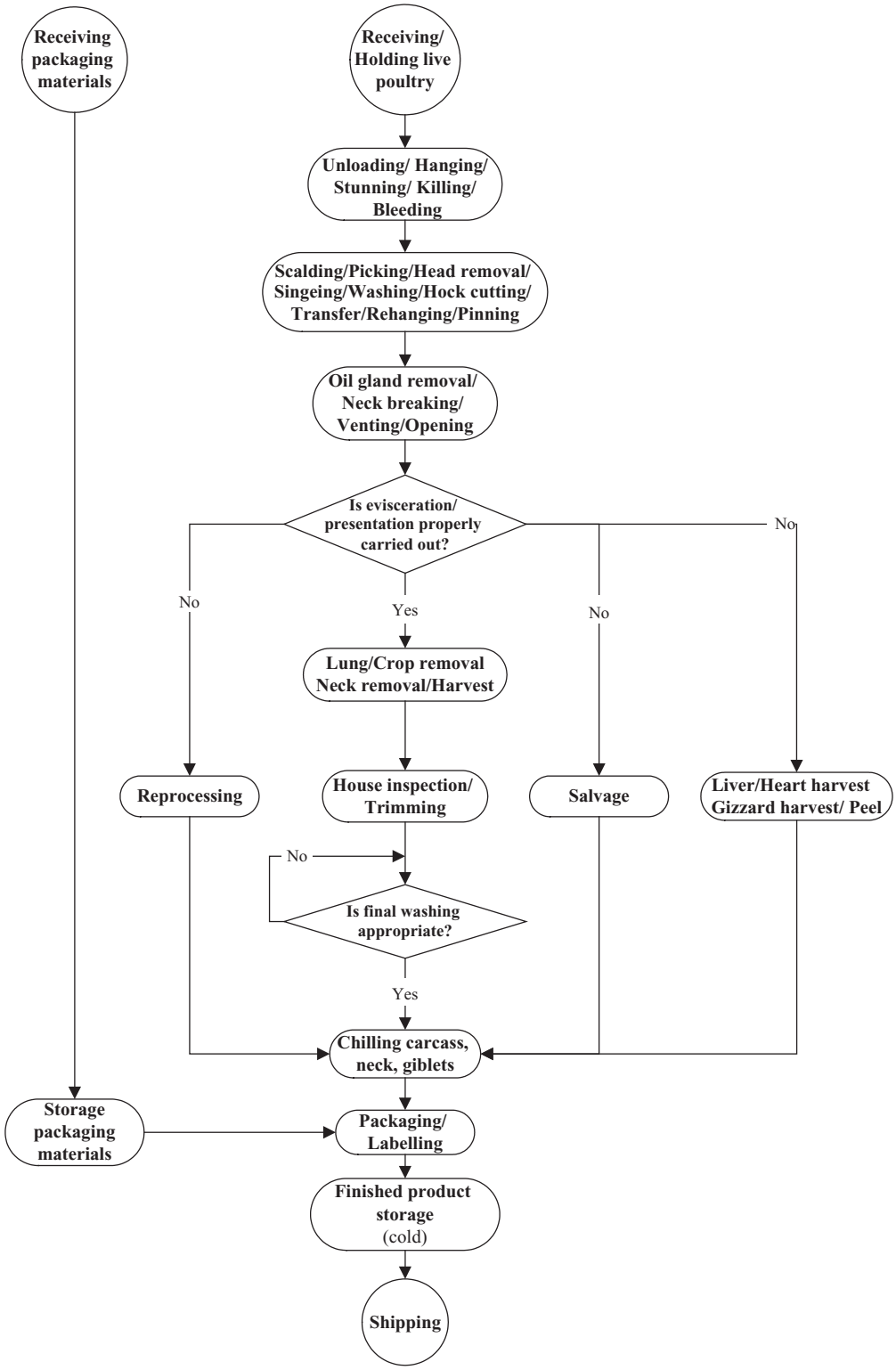

Fig. 5.2 Flow diagram of poultry slaughtering.

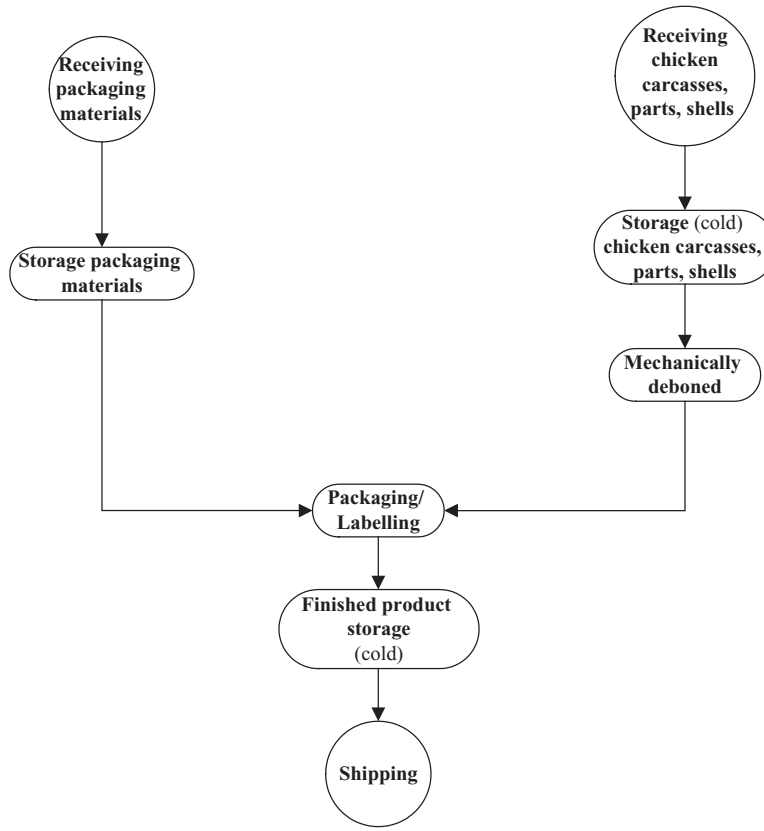

Fig. 5.3 Flow diagram of mechanically deboned chicken.

The National Advisory Committee on Microbiological Criteria for Foods (NACMCF, or the Committee) was asked to provide advice on developing guidelines for consumers for the safe cooking of poultry products. The questions were generated in response to foodborne illnesses from *Salmonella* related to the consumption of processed chicken products that appeared to be ready to eat (RTE) but contained poultry that was not ready to eat (NRTE). Information from an investigation of reports of salmonellosis in Minnesota and Michigan due to consumption of stuffed-chicken products, with a focus on labelling and retail product appearance, was also examined (Anonymous, 2007). The Committee determined that guidance for consumers is needed on cooking poultry products to achieve an adequate killing of pathogenic bacteria commonly associated with poultry and on interpreting the package labelling and cooking instructions. The adequacy of the killing treatment is affected by the product composition and geometry, temperature before cooking and crust formation. The guidance must also address the proper use of thermometers by the consumer and how to determine if the thermometer is working properly. The guidance should also describe the calibration of thermometers used by consumers and provide them with an understanding of the method for calibrating and the reason for calibrating. The recommendations of the Committee are based on seven questions posed by the FSIS. A summary of recommendations, either directed to consumers or to food processors, follows.

A single minimum internal product endpoint temperature of 73.9°C for cooking without a time limitation should be recommended to the consumer to ensure the microbiological safety of cooked poultry. This temperature will destroy *Salmonella*, the most heat-resistant pathogen of public health concern in raw poultry. Guidance to the consumer should indicate that higher final temperatures may be needed for consumer acceptability and palatability (e.g. 76.7°C for whole muscle breast meat, 82.2°C for whole muscle thigh meat in order to eliminate the pink appearance and

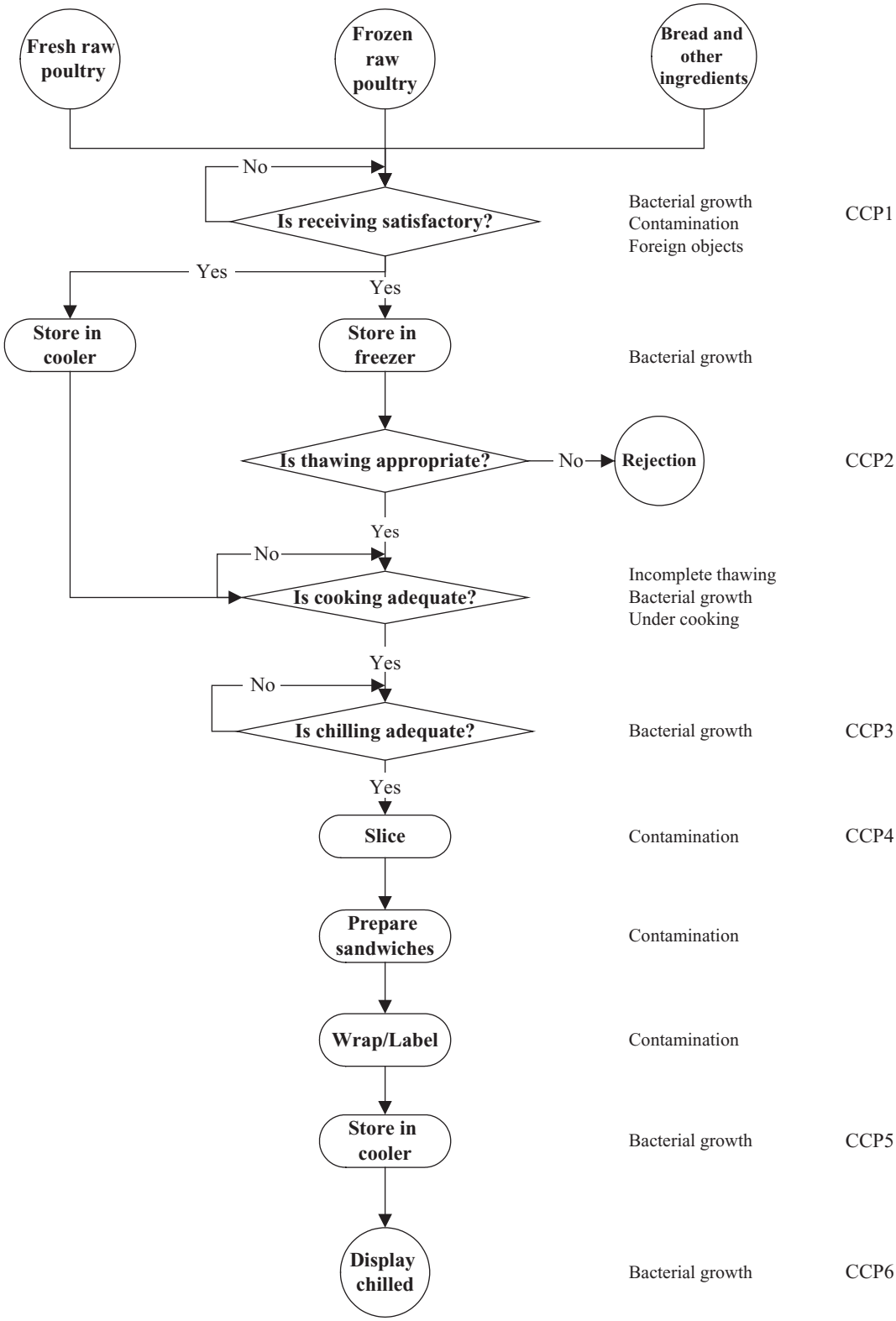

Fig. 5.4 Production of sliced poultry sandwich. The CCPs 1–6 were determined with HACCP in the absence of prerequisite programmes.

Table 5.6 Determination of critical control points for sliced poultry sandwich.

A/A	Step	Do control measure(s) exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of a hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable levels?	Will a subsequent step eliminate identified hazards or reduce likely occurrence to acceptable levels?	CCP
1	Receiving of fresh raw or frozen poultry	Yes	Yes			CCP1
2	Storage in cooler or freezer	Yes	No	No		cp
3	Thawing	Yes	No	No		cp
4	Cooking	Yes	Yes			CCP2
5	Chilling	Yes	Yes			CCP3
6	Slicing	Yes	Yes			CCP4
7	Sandwich preparation	Yes	No	No		cp
8	Wrapping-labelling	Yes	No	No		cp
9	Storage in cooler	Yes	Yes			CCP5
10	Chill display	Yes	Yes			CCP6

rubbery texture). The product condition or state before cooking should be considered in the guidelines and in the preparation–cooking instructions to the consumer. Guidelines for the consumer should convey that a longer cooking time is needed if the product is frozen at the beginning of the cooking process. The consumer should also be informed that microwaving raw product from the frozen state is not advisable unless the package provides substantial further instructions for ascertaining that the product has achieved

Table 5.7 ISO 22000 Analysis worksheet for the determination of prerequisite programmes for sliced poultry sandwich.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Receiving of fresh raw or frozen poultry	Yes	Yes	No	No	No
Storage in cooler or freezer	Yes	Yes	No	Yes	Yes
Thawing	Yes	Yes	No	Yes	Yes
Cooking	Yes	Yes	No	No	No
Chilling	Yes	Yes	No	No	No
Slicing	Yes	Yes	No	No	No
Sandwich preparation	Yes	Yes	No	Yes	Yes
Wrapping-labelling	Yes	Yes	No	Yes	Yes
Storage in cooler	Yes	Yes	No	No	No
Chill display	Yes	Yes	No	No	No

Table 5.8 CCPs of HACCP and ISO 22000 for sliced poultry sandwiches.

Process stage	CCP of HACCP	Prerequisite programme (ISO 22000)?	CCP of ISO 22000
Receiving of fresh raw or frozen poultry	1	No	1
Storage in cooler or freezer		Yes	
Thawing		Yes	
Cooking	2	No	2
Chilling	3	No	
Slicing	4	No	
Sandwich preparation		Yes	
Wrapping-labelling		Yes	
Storage in cooler	5	No	3
Chill display	6	No	

the recommended endpoint temperature. Guidance to the consumer should address how to properly measure product temperature. Instructions on how to calibrate the thermometer and on how to determine if it is out of calibration should be included, as well as a description of the purpose and importance of calibration. The product label should indicate if the product is RTE or NRTE. A warning on the label to fully cook a product may be necessary if the product is partially cooked or otherwise appears to be RTE. The principal display panel should be the primary focus for certain safety information (e.g. that the product contains uncooked poultry and must be cooked thoroughly for microbiological safety). When validating cooking instructions and developing guidelines or labelling, the process must take into account (i) how the consumer is likely to interpret the cooking instructions and (ii) how the consumer may actually prepare and cook the product. The cooking process must be designed to eliminate *Salmonella*, which is the most heat-resistant pathogen of public health concern for raw poultry. Although *L. monocytogenes* is more heat resistant, it is considered a hazard from post-process contamination rather than undercooking. The limitations of each type of process should be considered when developing and validating cooking guidelines or instructions. The limitations include difficulty of temperature measurement, uneven heating, equipment differences, a partially cooked surface that may make the product appear as if it is fully cooked, and the potential for having a cooked surface with an undercooked product interior. When a product containing uncooked poultry appears to be cooked, it is necessary to explicitly state on the label that the product contains uncooked poultry and must be thoroughly cooked.

Although approximately 95% of disease caused by non-typhoidal salmonella is transmitted by foodborne vehicles, four documented salmonella outbreaks in the 1990s have been traced to contact with young poultry. No environmental studies of source hatcheries were completed.

A case–control study was performed by Wilkins *et al.* (2002) comparing culture-confirmed *Salmonella infantis* in Michigan residents, identified between May and July 1999, with two age- and neighbourhood-matched controls. Eighty environmental and bird tissue samples were collected from an implicated hatchery; all salmonella isolates underwent PFGE analysis. The study included 19 case-patients sharing the same PFGE subtype and 37 matched controls. Within five days before illness onset, 74% of case-patients resided in households raising young poultry compared with 16% of controls. Eight hatchery samples yielded *S. infantis* with PFGE subtypes matching the patients' isolates. This investigation identified birds from a single hatchery as the source of human illness and confirmed the link by matching PFGE patterns from humans, birds and the hatchery environment. Subsequent public health interventions reduced, but did not eliminate, transmission of poultry-associated salmonellosis. Five additional PFGE-linked cases were identified in spring 2000, necessitating quarantine of the hatchery for depopulation, cleaning and disinfection.

The molecular epidemiology of 98 isolates of *Salmonella* serovar *Agona* ($n = 27$), *S. montevideo* ($n = 42$) and *S. senftenberg* ($n = 29$) from wild-living gulls, fish-meal factories, feed factories, humans and domestic animals was investigated by Nesse *et al.* (2005) using PFGE and computerised numerical analysis. Two of the *S. agona* profiles were identified both in gulls and in two of the factories. In addition, one of these profiles was detected in two infected poultry farms. Two of the *S. montevideo* profiles were also identified both in gulls and in two of the factories, and one of these profiles was observed in a human isolate.

Four factories shared an identical *S. senftenberg* profile. The *S. senftenberg* profile found in gulls was not identified in any other source investigated. The presence of isolates with identical PFGE profiles indicates potential epidemiological links between different factories, as well as between gulls and factories.

Rasekh *et al.* (2005) discuss policy changes since 1957 that the FSIS has made regarding handling of poultry carcasses that were accidentally contaminated by faeces or ingesta during slaughter and processing. Since 1957, FSIS has re-evaluated its position in the light of new scientific evidence on methods for handling contaminated poultry. The FSIS will continue to make scientifically supported changes that are consistent with HACCP principles. Prior to 1978, contamination was removed solely by knife trimming. In 1978, FSIS changed the regulations to allow reprocessing at special stations away from the main processing line. Several scientific studies demonstrated that the microbial quality of reprocessed product was comparable to carcasses remaining on the main processing line. Since 1996, FSIS has been actively reforming regulations to make them consistent with the Agency's HACCP system regulatory approach to meat, poultry and egg processing. Control of poultry contamination by digestive tract contents is one of several regulatory standards that have used a visible product standard. The visual absence of faeces or ingesta serves as an indirect measure of microbial safety for at least the risk from pathogens likely to be present in visible digestive tract contents. The FSIS strives to base regulatory reform on the best science available. Changes in processing methods, like reprocessing poultry to remove faeces and ingesta, were allowed because they improved the microbiological safety of final products. Such changes were tested prior to implementation to ensure that they were consistent with the goal of protecting public health.

Four hazards are likely to occur: physical contamination with faecal material and potential pathogen contamination at evisceration/presentation, pathogen contamination at reprocessing, pathogen cross-contamination and proliferation at chilling, and pathogen proliferation at finished products storage (cold). Four CCPs address these four hazards: proper evisceration/presentation, proper reprocessing, and proper chilling of product and proper maintenance of finished product temperatures during storage (Table 5.2). The ISO 22000 Analysis worksheet for the determination of prerequisite programmes for poultry slaughtering and synoptical presentation of HACCP plan are given in Tables 5.3 and 5.4, respectively. The comparison between CCPs of HACCP and ISO 22000 is shown in Table 5.5.

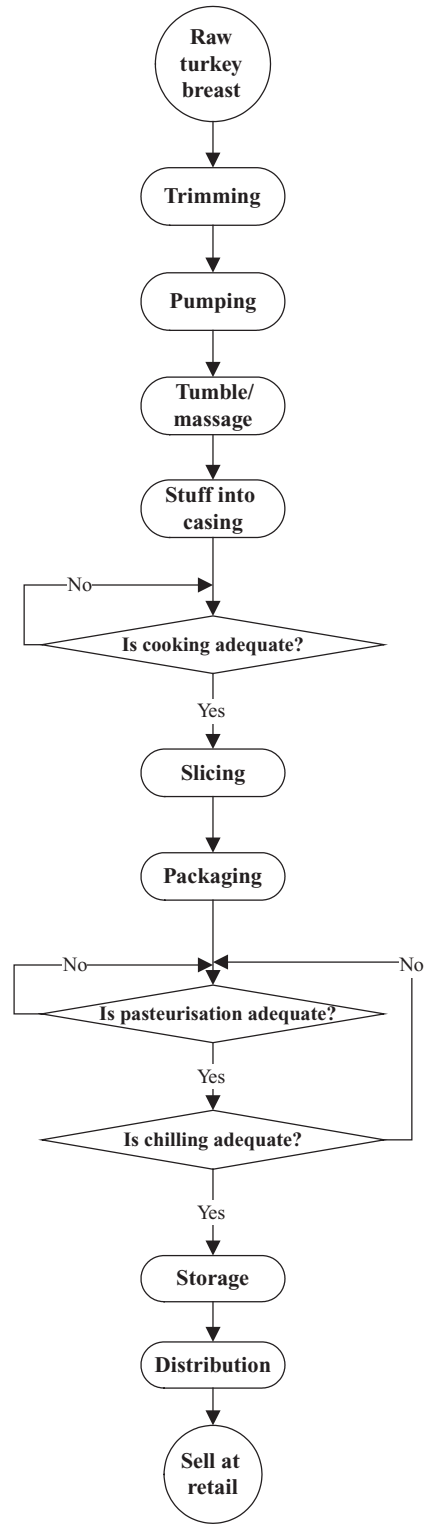

Fig. 5.5 Production of cooked sliced turkey meat.

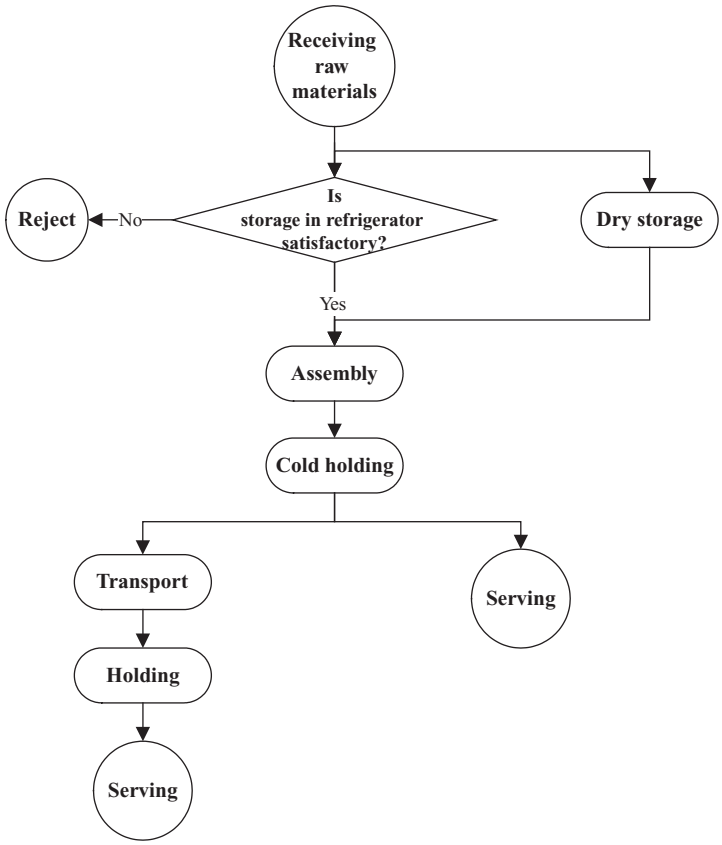

Fig. 5.6 Deli turkey sandwich preparation.

5.7 DIFFERENT RISK FACTORS – RISK ASSESSMENT

Newcastle disease (ND) is a highly pathogenic and contagious virus infection of poultry causing severe economic and production losses worldwide. The causative agent, ND virus (NDV), or avian paramyxovirus serotype-1 (APMV-1), is classified into velogenic, mesogenic and lentogenic strains (Beard and Hanson, 1984). Lentogenic strains are avirulent but mesogenic and velogenic strains cause mortality and nervous, respiratory and/or enteric clinical signs (Beard and Hanson, 1981). Velogenic strains of NDV cause acute disease and up to 100% mortality in non-immune domestic chickens. Newcastle disease is the most important infectious disease affecting free-range village chicken and the usual source of infection is assumed to be other chickens (Spradbrow, 1990).

A prospective study of risk factors associated with outbreaks of Newcastle disease (ND) in indigenous free-range chickens was carried out by Otim *et al.* (2007) in three agro-ecological zones in eastern Uganda. Sixty households keeping chickens were randomly selected and studied from March 2004 to February 2005, covering rainy and dry seasons. Data on ND outbreaks, risk factors and flock dynamics were collected using an interviewer-administered questionnaire, while ND outbreaks were confirmed by haemagglutination inhibition test. Multivariate survival analyses were performed to identify the risk factors for Newcastle disease outbreaks.

Their study identified restocking chickens from the market and the neighbourhood as the most important risk factors for ND outbreaks. This supports earlier observations that live infected birds are the most likely means of introduction of NDV into village populations and that the live bird markets represent a major source of infected poultry (Nguyen, 1992).

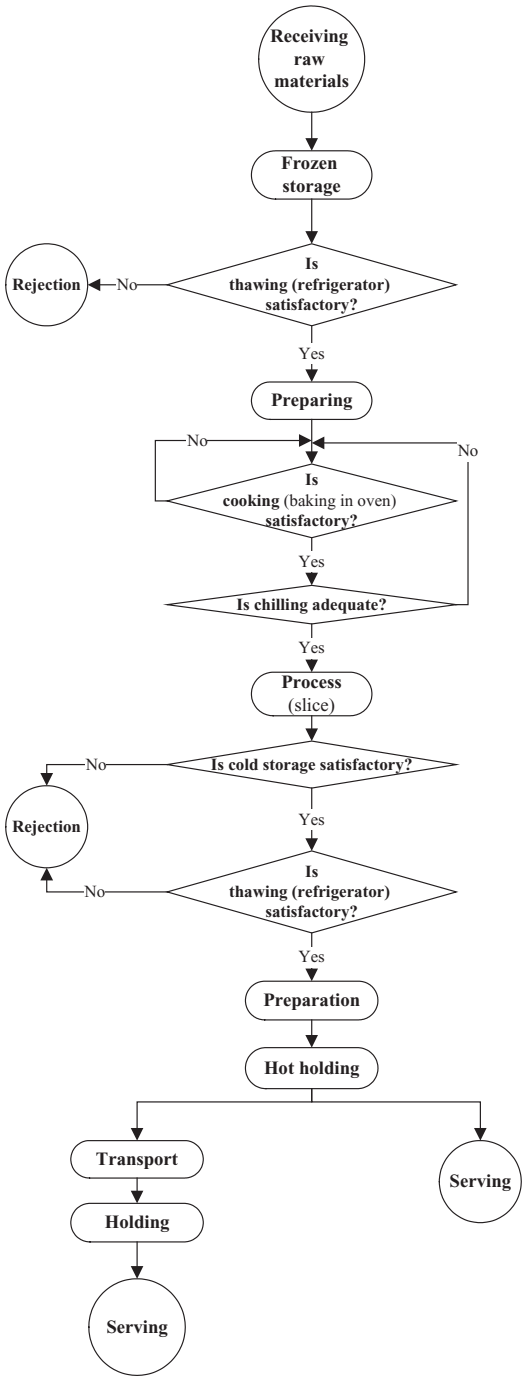

Fig. 5.7 Raw turkey breast cooking and serving.

Causal inference of exposure–response relations from data is a challenging aspect of risk assessment with important implications for public and private risk management. Such inference, which is fundamentally empirical and based on exposure (or dose)–response models, seldom arises from a single set of data; rather, it requires integrating heterogeneous information from diverse sources and disciplines including epidemiology, toxicology and cell and molecular biology. The causal aspects focus on these three aspects:

- drawing sound inferences about causal relations from one or more observational studies;
- addressing and resolving biases that can affect a single multivariate empirical exposure–response study; and
- applying the results from these considerations to the microbiological risk management of human health risks and benefits of a ban on antibiotic use in animals, in the context of banning enrofloxacin or macrolides, antibiotics used against bacterial illnesses in poultry, and the effects of such bans on changing the risk of human foodborne campylobacteriosis infections.

Cox and Ricci (2005) described novel causal methods for assessing empirical causation and inference; exemplified how to deal with biases that routinely arise in multivariate exposure – or dose–response modelling; and provide a simplified discussion of a case study of causal inference using microbial risk analysis as an example. The case study supports the conclusion that the human health benefits from a ban are unlikely to be greater than the excess human health risks that it could create, even when accounting for uncertainty. They concluded that quantitative causal analysis of risks is preferable to qualitative assessments because it does not involve unjustified loss of information and is sound under the inferential use of risk results by management.

The Workgroup on the Potential Role of CAFOs in Infectious Disease Epidemics and Antibiotic Resistance raised concerns about the practice of co-locating swine and poultry facilities and the spectre of a global pandemic arising from new strains of avian influenza incubated in swine and transmitted to humans (Gilchrist *et al*., 2007). They recommended that minimum separation distances should be established and that animals should not be fed tissues, faecal matter or contaminated water from other animals. This workgroup stated that solid tanks for storage of manure and municipal style waste treatment are necessary to limit microbial contamination of soil and water, prevent access to waterfowl and limit the spread of disease.

Table 5.9 Determination of critical control points for raw turkey breast.

A/A	Step	Do control measure(s) exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of a hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable levels?	Will a subsequent step eliminate identified hazards or reduce likely occurrence to acceptable levels?	CCP
1	Receiving of ingredients	Yes	Yes			CCP1
2	Frozen storage	Yes	Yes			CCP2
3	Thawing	Yes	No	No		cp
4	Preparation	Yes	No	No		cp
5	Cooking	Yes	Yes			CCP3
6	Chilling	Yes	Yes			CCP4
7	Slicing	Yes	No	No		cp
8	Freezing	Yes	Yes			CCP5
9	Thawing	Yes	No	No		cp
10	Preparation	Yes	No	No		cp
11	Hot hold	Yes	Yes			CCP6
12	Serving	Yes	No	No		cp

Management practices such as feeding animals with antimicrobial growth promotants and housing poultry and swine in proximity are additional concerns (Thorne, 2007).

Mix-ELISA using lipopolysaccharide antigens from *Salmonella enterica* serotype *Enteritidis* and *Typhimurium* was evaluated by Feld *et al.* (2000) using samples collected over time in the Danish salmonella surveillance programme for poultry. Serological samples ($n = 42{,}813$) taken from broiler-breeder flocks after a year of bacteriological monitoring with negative results were used for calculating the flock and individual test specificities, which were 0.997 and 0.999, respectively. Layer flocks from the table egg sector were

Table 5.10 ISO 22000 Analysis worksheet for the determination of prerequisite programmes for raw turkey breast.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Receiving of ingredients	Yes	Yes	No	No	No
Frozen storage	Yes	Yes	No	No	No
Thawing	Yes	Yes	No	Yes	Yes
Preparation	Yes	Yes	No	Yes	Yes
Cooking	Yes	Yes	No	No	No
Chilling	Yes	Yes	No	No	No
Slicing	Yes	Yes	No	Yes	Yes
Freezing	Yes	Yes	No	No	No
Thawing	Yes	Yes	No	Yes	Yes
Preparation	Yes	Yes	No	Yes	Yes
Hot hold	Yes	Yes	No	No	No
Serving	Yes	Yes	No	Yes	Yes

Table 5.11 CCPs of HACCP and ISO 22000 for raw turkey breast.

Process stage	CCP of HACCP	Prerequisite programme (ISO 22000)?	CCP of ISO 22000
Receiving of ingredients	1	No	1
Frozen storage	2	No	
Thawing		Yes	
Preparation		Yes	
Cooking	3	No	2
Chilling	4	No	
Slicing		Yes	
Freezing	5	No	
Thawing		Yes	
Preparation		Yes	
Hot hold	6	No	3
Serving		Yes	

used for calculation of positive predictive values. In the survey, flocks were examined for salmonella by Mix-ELISA and by faecal culture, and in case of a positive result in either of these a repeated, serological testing was performed and 60 animals were organ-cultured. If one of these samplings was positive, the flock was declared salmonella infected. In a period of three months, 35 flocks were found to be positive in the routine samples (Feld *et al.*, 2000).

Of these, 32 were serologically positive, two both serologically and faecally positive and one flock only faecally positive. For flocks serologically positive in the surveillance programme, a positive-predictive value of 0.62 for organ culture positivity was found, and while considering serological follow-up samples, the value was 0.95.

Salmonella is a major pathogen associated with poultry food products. Over the past 20 years, pressure to reduce human illness from poultry-related salmonellosis has resulted in intensive research activity as well as stronger regulatory standards in Europe, North America, and, because of international trade policies, throughout the world. In the United States, implementation of a HACCP-based inspection programme has been credited with reducing the incidence of *Salmonella*-positive carcasses from approximately 20 to 10%. Since 1998, however, the reported incidence of *Salmonella* in retail poultry from 12 countries implementing similar pathogen reduction programmes, including the United States, has averaged 29% positive for *Salmonella*. Although these reports examined products at retail outlets and used a variety of sampling methodologies, these results appear to contradict the US Department of Agriculture claims for *Salmonella* reduction. Fletcher (2006) reviewed

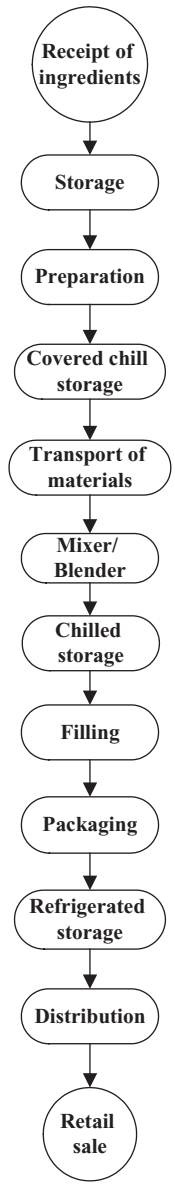

Fig. 5.8 Production of refrigerated chicken salad.

this contradiction by focusing on the potential impact of sampling methodology on reported incidences of *Salmonella*.

One hundred and thirteen isolates of *Salmonella* serotype Thompson from diverse sources in seven countries were characterised by *Pvu*II ribotyping and IS*200* fingerprinting. Ten *Pvu*II ribotypes were observed. The predominant *Pvu*II ribotype 1 represented a major clone of worldwide distribution but

Table 5.12 Determination of critical control points for refrigerated chicken salad.

A/A	Step	Do control measure(s) exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of a hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable levels?	Will a subsequent step eliminate identified hazards or reduce likely occurrence to acceptable levels?	CCP
1	Receiving of ingredients	Yes	Yes			CCP1
2	Storage	Yes	No	No		cp
3	Preparation	Yes	No	No		cp
4	Covered chilled storage	Yes	Yes			CCP2
5	Transport of materials	Yes	Yes			CCP3
6	Mixing/blending	Yes	No	No		cp
7	Chilled storage	Yes	Yes			CCP4
8	Filling	Yes	No	No		cp
9	Packaging	Yes	No	No		cp
10	Refrigerated storage	Yes	Yes			CCP5
11	Distribution	Yes	Yes			CCP6
12	Retail sale	Yes	No	No		cp

is not found in Australia; *Pvu*II ribotypes 2 and 3 represented minor clones. *Hin*cII ribotyping discriminated subtypes within *Pvu*II ribotype 1: *Hin*cII ribotype 1 was distributed widely but *Hin*cII ribotype 2 was found mainly in Scottish isolates (Chisholm *et al*., 1999).

None of 101 isolates of *Pvu*II ribotypes 1–3 contained copies of IS*200*. All 12 isolates of *Pvu*II ribotypes 4–10 were from Australia and seven of them contained copies of IS*200* of five different profiles. These results suggest the existence of at least two lineages of *Salmonella* Thompson with a different geographical distribution. The finding that most isolates from humans and poultry in Scotland belonged to the same ribotype (*Pvu*II 1 and *Hin*cII 2) and were IS200-negative suggests that poultry is an important source of human infection in Scotland.

The prevalence of *Campylobacter* and *Salmonella* spp. was determined from live bird to prepackaged carcass for three flocks from each of six types of California niche-market poultry by McCrea *et al*. (2006). Commodities sampled included squab, quail, guinea fowl, duck, poussin (young chicken) and free-range broiler chickens. *Campylobacter* on-farm prevalence was lowest for squab, followed by guinea fowl, duck, quail and free-range chickens. Poussin had the highest prevalence of *Campylobacter*. No *Salmonella* was isolated from guinea fowl or quail flocks. A few positive samples were observed in duck and squab, predominately of *S. typhimurium*. Free-range and poussin chickens had the highest prevalence of *Salmonella*. Post-transport prevalence was not significantly higher than on-farm, except in free-range flocks, where a higher prevalence of positive chickens was found after 6–8 hours holding before processing. In most cases, the prevalence of *Campylobacter*- and *Salmonella*-positive birds was lower on the final product than on-farm or during processing. Odds ratio analysis indicated that the risk of a positive final product carcass did not increase by the prevalence of a positive sample at an upstream point in the processing line, or by on-farm prevalence (i.e. none of the common sampling stations among the six commodities could be acknowledged as CCPs). This suggests that HACCP plans for *Campylobacter* and *Salmonella* control in the niche-market poultry commodities will need to be specifically determined for each species and per processing facility.

Poultry meat is an important source of *Salmonella* infections in humans. Chicken has been found to be associated with foodborne disease outbreaks of *S. enteritidis* infections in England and Wales (Cowden *et al*., 1995). Chicken bought ready-to-eat has been

Table 5.13 ISO 22000 Analysis worksheet for the determination of prerequisite programmes for refrigerated chicken salad.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Receiving of ingredients	Yes	Yes	No	No	No
Storage	Yes	Yes	No	Yes	Yes
Preparation	Yes	Yes	No	Yes	Yes
Covered chilled storage	Yes	Yes	No	No	No
Transport of materials	Yes	Yes	No	No	No
Mixing/blending	Yes	Yes	No	Yes	Yes
Chilled storage	Yes	Yes	No	No	No
Filling	Yes	Yes	No	Yes	Yes
Packaging	Yes	Yes	No	Yes	Yes
Refrigerated storage	Yes	Yes	No	No	No
Distribution	Yes	Yes	No	No	No
Retail sale	Yes	Yes	No	Yes	Yes

implicated in an outbreak of *Salmonella typhimurium* infections in France, in sporadic cases of *S. enteritidis* infections in Great Britain, and more recently as a risk factor for the increase of *Salmonella* Hadar infection observed in France.

The study by Delarocque-Astagneau *et al.* (1998) indicates that the risk of *S. enteritidis* infection acquired through the consumption of contaminated eggs, egg products and poultry at home may be reduced by limiting the length of storage of eggs and eating eggs and chicken well done.

Nitrofurans comprise a group of antibiotic substances that have been used widely in the past in intensive farming of pigs, poultry, fishes and shrimps (Hoenicke and Gatermann, 2006). Studies in the late 1980s and early 1990s have proven that they are metabolised shortly after administration and form persistent residues that could be detected in the tissues of treated animals for weeks after administration. Both the nitrofurans as well as special metabolites have been classified as genotoxic compounds. No maximum residue limit (MRL) could be fixed either due to a lack of data or because the toxicological data did not support the derivation of an acceptable daily intake (ADI). Therefore, nitrofurans are listed in Annex IV of Council Regulation EEC No. 2377/90. From a regulatory point of view, any exposure to those substances is deemed a hazard to human health. Consequently, Annex IV substances are controlled with zero tolerance.

Table 5.14 CCPs of HACCP and ISO 22000 for refrigerated chicken salad.

Process stage	CCP of HACCP	Prerequisite programme (ISO 22000)?	CCP of ISO 22000
Receiving of ingredients	1	No	1
Storage		Yes	
Preparation		Yes	
Covered chilled storage	2	No	
Transport of materials	3	No	
Mixing/blending		Yes	
Chilled storage	4	No	
Filling		Yes	
Packaging		Yes	
Refrigerated storage	5	No	2
Distribution	6	No	3
Retail sale		Yes	

Histamine is a biogenic amine naturally present in various living organisms and responsible for many physiological and pathophysiological functions. It is also known as an environmental toxin produced in high amounts in feedstuffs by micro-organisms through activity of histidine decarboxylase. High histamine level of this origin is most frequently present in fish and fish products. Symptoms and diseases are caused in humans (scombrotoxism) and poultry (gizzard erosions and ulcers) by food rich in high histamine level (Harry *et al.*, 1975). Histamine levels of 1–2 g/kg are considered sufficient for development of toxic effects in chickens and fish (Barnes *et al.*, 2001).

Fish meal is produced from fish meat and residues, or as a by-product of fish oil production. It is mainly

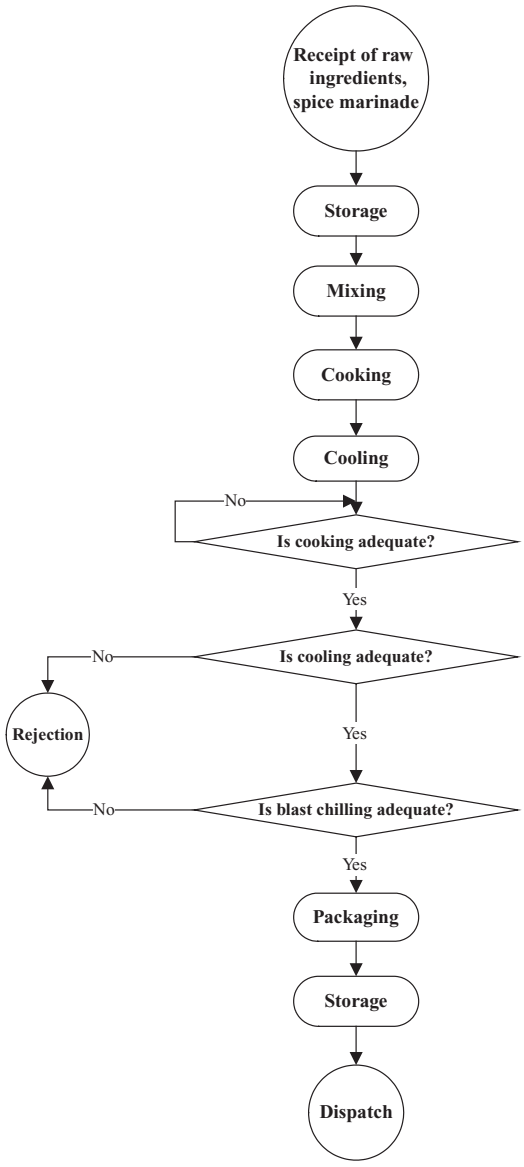

Fig. 5.9 Process flow diagram of chilled chicken curry.

used as a fertiliser and animal feed ingredient, especially for poultry, cultured fish and shrimps and livestock. Fish meal and other feedstuff with a high content of histamine should be considered as potential long-term health hazard for people who handle them and also for poultry and other animals if used as a feed (Macan *et al*., 2006). This study confirmed the long-term persistence of histamine in contaminated fish meal. Histamine was present at the highly toxic level (>2 g/kg) for more than 3 years if stored at 4–8°C, and for at least 3 months if kept at ambient temperature (24°C) unprotected from light. The results confirmed their previous hypothesis that fish meal with a high content of histamine is a potential long-term health hazard for poultry and other animals if used as a feedstuff and also for men manipulating it.

Thermophilic *Campylobacter* species have now been recognised as a major cause of bacterial gastrointestinal infections in humans. Thermophilic *Campylobacter* spp., i.e., those *Campylobacter* spp. that are able to proliferate at 42°C, particularly *C. jejuni*, *C. coli* and *C. lari*, are of particular interest to the food industry. *C. jejuni* is responsible for 80–90% of foodborne *Campylobacter* infections worldwide (Park, 2002).

Campylobacter spp. are carried in the intestinal tract of cattle, pigs and chickens and transmitted to meat products by contact with their excreta during the slaughtering process. Contaminated meat is the main source of campylobacteriosis (Butzler and Oosterom, 1991). Retail fresh poultry has been identified as being responsible for many foodborne outbreaks. Inadequately cooked meat, particularly poultry, unpasteurised milk and contaminated drinking water are the most common causes of epidemic and sporadic foodborne cases (Altekruse *et al*., 1999). Furthermore, cross-contamination of other foods caused by raw poultry meat during food preparation is also likely to be important.

From May to August 2004, 127 samples of chicken meat for sale on the retail market in Ankara were analysed by Savasçi and Özdemir (2006) for the prevalence of thermophilic *Campylobacter* spp. *Campylobacter* spp. were isolated from 83.4% of the samples analysed. *C. jejuni* was found in 74.8% of all samples. A total of 364 thermophilic *Campylobacter* strains were isolated and the species distribution among these strains was 70.1% *C. jejuni*, 21.1% *C. coli* and 8.6% *C. lari*. The results obtained from the study indicate that hygienic and technical compliance is needed in all stages of poultry processing to reduce contamination and to prevent a public health hazard. An integrated HACCP plan must be applied from the farm to the table for the prevention of *C. jejuni* infections.

Campylobacter contamination ranged from 47 to 81% between different producers. However, no temporal association between contamination of chickens and human *Campylobacter* infections, was found indicating that many cases of human campylobacteriosis, particularly during seasonal peaks, do not originate from chickens.

Control measures that have reduced salmonella contamination have been largely ineffective against

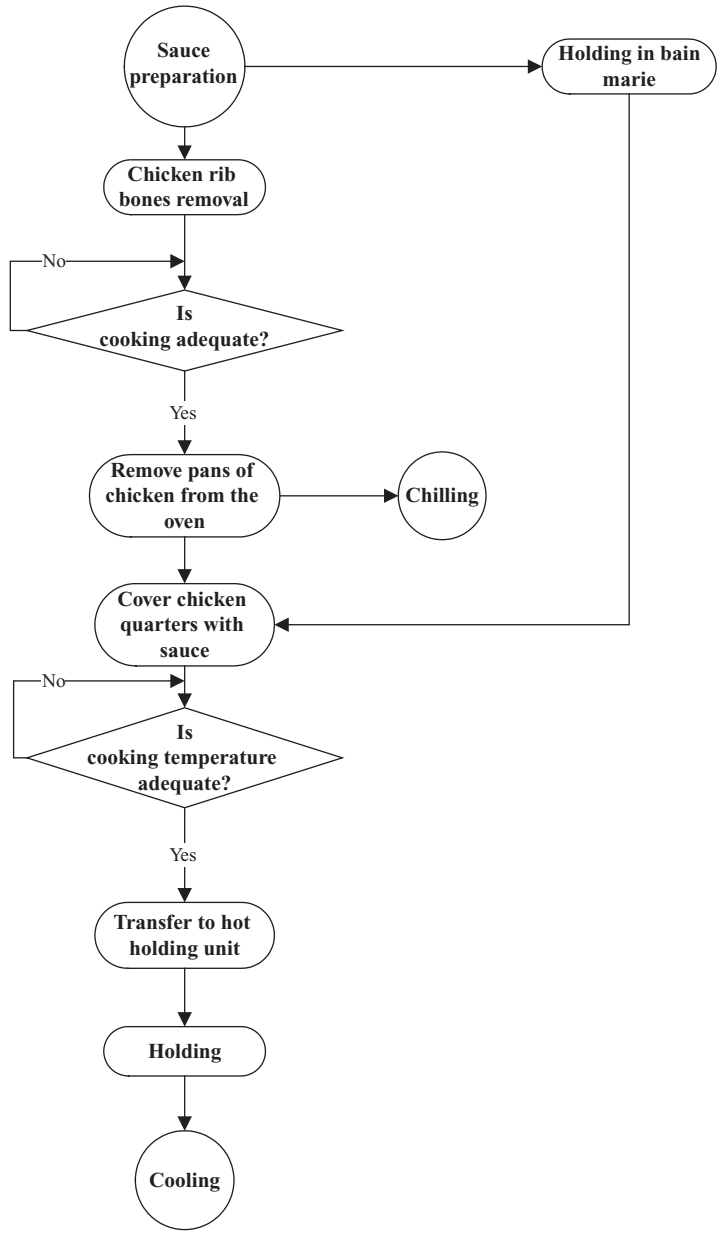

Fig. 5.10 Chicken cacciatore QA recipe.

Campylobacter and new interventions are needed. Most raw chickens are contaminated with these pathogens, and communicating the importance of minimising this risk to caterers and the public is vital in reducing human infections.

In the Netherlands, a national programme for the surveillance of zoonotic bacteria in farm animals has been operative since 1997. Van de Giessen *et al.* (2006) described the results of the surveillance of *Salmonella* spp. in flocks of laying hens and broilers and of *Campylobacter* spp. in broiler flocks in the period 1999–2002. The prevalence of *Salmonella* spp. in laying-hen flocks has significantly decreased from 21.1% in 1999 to 13.4% in 2002. This decreasing

Table 5.15 Determination of critical control points for chilled chicken curry.

A/A	Step	Do control measure(s) exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of a hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable levels?	Will a subsequent step eliminate identified hazards or reduce likely occurrence to acceptable levels?	CCP
1	Receiving of ingredients	Yes	Yes			CCP1
2	Storage	Yes	No	No		cp
3	Mixing	Yes	No	No		cp
4	Cooking	Yes	Yes			CCP2
5	Cooling	Yes	Yes			CCP3
6	Blast chilling	Yes	Yes			CCP4
7	Packaging	Yes	No	No		cp
8	Storage	Yes	Yes			CCP5
9	Dispatch	Yes	Yes			CCP6

trend might indicate that the control measures taken by the poultry industry were effective. *S. enteritidis* was the predominant serovar in laying hens accounting for one third of the positive flocks. Although prevalence estimates for *Salmonella* spp. in broiler flocks did not yield a significant decreasing trend in 1999–2002, a decrease in *Salmonella* prevalence to 11% was measured in 2002. During the study period, *S. paratyphi* B var. Java emerged in broilers to become the predominant serovar in 2002 accounting for one third of the positive flocks. The prevalence of *Campylobacter* spp. in broiler flocks did not increase nor decrease continuously between 1999 and 2002, which roughly corresponds with the monitoring results from the poultry industry. In this period, the estimated flock prevalence roughly averaged around 20%, with *C. jejuni* being the predominant species. The approach of monitoring can serve as a blueprint for monitoring schemes in farm animal populations to be developed in the context of the EC Zoonoses Directive.

Table 5.16 ISO 22000 Analysis worksheet for the determination of prerequisite programmes for chilled chicken curry.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Receiving of ingredients	Yes	Yes	No	No	No
Storage	Yes	Yes	No	Yes	Yes
Mixing	Yes	Yes	No	Yes	Yes
Cooking	Yes	Yes	No	No	No
Cooling	Yes	Yes	No	No	No
Blast chilling	Yes	Yes	No	No	No
Packaging	Yes	Yes	No	Yes	Yes
Storage	Yes	Yes	No	No	No
Dispatch	Yes	Yes	No	No	No

Polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) are widely recognised by the scientific community as persistent organic pollutants due to their toxicity and adverse effects on wildlife and human health. The actual regulation dedicated to the monitoring of dioxins in food is based on the measurement of 17 congener concentrations. The final result is reported as a toxic equivalent value that takes into account the relative toxicity of each congener. This procedure can minimise the qualitative information available from the abundances of each PCDD/PCDF congener: the characteristic contamination profile of the sample. Multivariate statistical techniques, such as principal component analysis (PCA) or linear discriminant analysis (LDA), represent an interesting way to investigate this qualitative information.

Antignac *et al*. (2006) investigated the variability of the PCDD/PCDF contamination profile across a wide array of food products of animal origin using multivariate statistical analysis. The results demonstrated the existence of differences between the analysed samples in term of congener-specific patterns. A variability that depends upon the sample nature (fish, meat, milk, fatty products) was first demonstrated. A variability that depends upon the animal species for meat and milk samples (bovine, ovine, porcine, caprine and poultry) was then observed. Figure 5.2 describes this process and the flow diagram of mechanically deboned chicken is given in Fig. 5.3.

5.8 DIFFERENT KINDS OF POULTRY MEALS

The incoming raw materials and ingredients for production of sliced poultry sandwich (Fig. 5.4) should be obtained from sources that comply with current legislation and should be regularly tested for their quality (Krug, 1995). The sliced poultry sandwiches should be displayed chilled because they constitute a favourable substrate for bacterial growth. Temperature should be constantly maintained below 5°C and ready-to-eat products should not be displayed in physical contact with raw materials (Bryan, 1981). The determination of CCPs and the ISO 22000 analysis worksheet for the determination of prerequisite programmes for sliced poultry sandwich are summarised in Tables 5.6 and 5.7, respectively. The comparison between CCPs of HACCP and ISO 22000 for sliced poultry sandwiches is shown in Table 5.8.

The same process is followed for production of cooked sliced turkey meat and deli turkey sandwich (Figs. 5.5 and 5.6, respectively).

Table 5.17 CCPs of HACCP and ISO 22000 for chilled chicken curry.

Process stage	CCP of HACCP	Prerequisite programme (ISO 22000)?	CCP of ISO 22000
Receiving of ingredients	1	No	1
Storage		Yes	
Mixing		Yes	
Cooking	2	No	2
Cooling	3	No	3
Blast chilling	4	No	
Packaging		Yes	
Storage	5	No	
Dispatch	6	No	

Raw turkey breast can be the primary vector of harmful micro-organisms in the final product (Fig. 5.7; Hopkins and Scott, 1983). The main micro-organisms are *E. coli*, *Salmonella*, *S. aureus*, *L. monocytogenes* and *Yersinia enterocolitica* (Pini and Guilbert, 1988). Cooking at a relatively low temperature and for a short period of time aims at the reduction of the microbiological load of the raw turkey, the inactivation of enzymes and the removal of foreign material (Mossel *et al*., 1998). Cooling should be carried out as promptly as possible to prevent the growth of *C. botulinum* and other micro-organisms that may survive heating. Turkey breasts should be chilled at 4°C within 3 hours and maintained at this temperature throughout the distribution chain until consumed. Care must be taken to avoid cross-contamination from raw products stored in the same refrigerator (Mossel *et al*., 1995). The determination of CCPs and the ISO 22000 analysis worksheet for the determination of prerequisite programmes for raw turkey breast are given in Tables 5.9 and 5.10, respectively. The comparison between CCPs of HACCP and ISO 22000 for raw turkey breast is summarised in Table 5.11.

Chicken salad is a product frequently implicated as a vehicle in foodborne illness. The micro-organisms of greatest concern in *L. monocytogenes* because of its ability to grow at low temperatures and to survive at reduced pH values, and its recognition as an environmental contaminant of food plants (Mossel *et al*., 1995). Chicken salad is a complex product, consisting of many different ingredients. The ingredients included in the salad are cooked chicken, dressing, diced celery, onion, bread crumbs, diced sweet pickles and pickle relish, peppers, hard boiled eggs, chicken broth and spices (Bryan *et al*., 1980). The flow diagram describing the production of chicken

salad is shown in Fig. 5.8. The determination of CCPs and the ISO 22000 analysis worksheet for the determination of prerequisite programmes for chicken salad are given in Tables 5.12 and 5.13, respectively. The comparison between CCPs of HACCP and ISO 22000 for refrigerated chicken salad is summarised in Table 5.14.

During storage, the internal temperature of the materials should not exceed 7°C in order to prevent microbiological growth. For this purpose, refrigerators should be equipped with calibrated temperature-measuring devices which function and record continuously and allow free airflow around the materials. As mentioned earlier, the most important microbiological hazard during the preparation of the salad is *L. monocytogenes* (Stier, 1992).

In the production of chilled chicken curry, raw chicken can be contaminated with *Salmonella*, *Campylobacter* and other pathogens (Mossel *et al*., 1995). Sauce can introduce further microbiological hazard since spices are a potential source of the spore-forming bacteria *Bacillus* and *Clostridium*, coliforms and the fungus *Aspergillus glaucus* (Pitt and Christian, 1968). The flow diagram of the production of chilled chicken curry is given in Fig. 5.9. Finally, the flow diagram of chicken cacciatore QA recipe is given in Fig. 5.10. The determination of CCPs and the ISO 22000 analysis worksheet for the determination of prerequisite programmes for chilled chicken salad are summarised in Tables 5.15 and 5.16. The comparison between CCPs of HACCP and ISO 22000 for chilled chicken curry is summarised in Table 5.17.

5.9 CONCLUSION

As a concluding remark, it can be said that *Salmonella*, *Campylobacter* and *C. botulinum* can be effectively dealt with proper heating (appropriate temperature and time, GMP) whereas cross-contamination problems due to *Staphylococcus*, *Listeria* etc. can be removed within the frame of GHP. Therefore, implementation of ISO 22000 where GMP and GHP are prerequisite programmes will be advantageous to the poultry industry.

Combined FSIS data for 1998–2002 period showed that *Salmonella* prevalence in all meat products decreased to levels below the baseline prevalence estimates determined prior to HACCP implementation. The data indicated that ground chicken averages 19.8% under HACCP compared to 44.6% prior HACCP and ground turkey averages 26.6% compared to 49.9% (Rawson, 2003).

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6
Eggs

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6.1 INTRODUCTION – HAZARDS

The term 'eggs' applies to the entire eggs of hens, which are suitable for consumption and for industrial production of food products intended for human consumption. In the USA, over 46 billion eggs per year were distributed, sold and used as shell eggs (FSIS, 1998). The FSIS's egg risk assessment and calculations based upon surveillance studies estimated that 2.3 million of these eggs contain *Salmonella enteritidis* (SE) when laid (FSIS, 1998). Public health surveillance data estimated that there are 637,000 cases of human illness per year from the consumption of contaminated raw or undercooked eggs.

The *S. enteritidis* serotype is unique in its ability to asymptomatically colonise the reproductive tract of a hen and become entrapped in the egg albumen as the egg is being formed. SE can survive in the albumen, but it is effectively inhibited from growing for an extended period of time. This inhibition results from an increasing albumen pH from 7.2 to over 9.0 during the initial days after laying. Albumen proteins that inhibit SE include ovomucin which binds iron, avidin which binds biotin and lysozyme which disrupts the bacterial membranes. In contrast to the albumen, the yolk is a rich microbial medium with little capability of inhibiting SE growth. The ability of the yolk membrane to separate the bacteria and the yolk's nutrients is a critical factor in controlling the egg's SE population (Humphrey, 1994).

Studies and industry experience have shown that the egg can resist SE growth for approximately 2–3 weeks at room temperature (Humphrey, 1994). Other serotypes of *Salmonella* and other microflora, both spoilage organisms and pathogens, may be present on the exterior of the shell. Under appropriate conditions, these micro-organisms were shown to penetrate through the shell's pores and the two adjacent membranes (Chen *et al*., 1996). Cracked eggs may permit entry of external micro-organisms, both spoilage and pathogenic species (Todd, 1996).

Whiting *et al*. (2000) reported on a stochastic model estimating growth of *S. enteritidis* during egg collection, processing, storage and transportation. The model contains equations for internal egg temperature, yolk membrane integrity and exponential growth rate of *S. enteritidis*. Monte Carlo simulations determined that no growth was likely to occur during the average 4.5 days of the egg's progression from lay through transportation. However, various time–temperature combinations affected the subsequent abuse an egg can withstand before *S. enteritidis* growth begins. Scenarios demonstrated the relative importance of ambient air temperature and indicated that the greatest safety improvements in this phase for shell eggs would result from preventing unrefrigerated storage or hastening cooling immediately after lay.

Miyamoto *et al*. (1998) reported on the ability of *S. enteritidis* to penetrate shell eggs due to post-processing chilling. Analysis of the *Salmonella enterica* serovar *enteritidis* cell surface revealed that certain wild-type strains efficiently produce a capsule-like O-chain region of lipopolysaccharide (LPS), known as high-molecular-mass LPS (HMM LPS), whereas *S. enterica* serovar *typhimurium* does not produce this region. Production of HMM LPS correlates with high-cell density growth, swarm cell differentiation on hard agar surfaces, and a high incidence of egg contamination in hens (Guard-Petter, 2001; Parker and Guard-Petter, 2001).

Morales *et al*. (2005) correlated variant phenotypes of *S. enterica* serovar *enteritidis* with genotypes by making two sets of comparisons between three prototypical strains that together represent (i) the

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two major phage-type lineages, PT4 and non-PT4, and (ii) two subpopulations with variant phenotypes that vary in the ability to contaminate eggs within a single non-PT4 lineage phage type, PT13A. This approach was possible because of the availability of new information about the completed *S. enterica* serovar Enteritidis PT4 genome (sequence data produced by the Beowulf Genomics Sequencing Group at the Sanger Institute, which can be obtained at http://ftp.sanger.ac.uk/pub/pathogens/Salmonella/SEpt4.dbs) and because of the development of high-throughput Phenotype MicroArrays that assay the growth of bacteria by measurement of respiratory activity in response to 1920 different culture conditions. The three strains surveyed for phenotypic differences were a field isolate of *S. enterica* serovar *enteritidis* PT4, a wild-type *S. enterica* serovar Enteritidis PT13A strain and a biofilm-forming *S. enterica* serovar *enteritidis* PT13A strain, whereas genomic comparisons were made by using microarrays to compare the gene contents of the two PT13A strains and the available genomic sequence of *S. enterica* serovar *enteritidis* PT4. The phenotype of each strain was examined at 25 and 37°C, because temperature is a known regulator of cell surface properties of *S. enterica* serovar *enteritidis*.

Moreover, Morales *et al.* (2005) found that the different physiologies of the *S. enterica* serovar *enteritidis* strains correlated most closely with minor, rather than major, genomic changes. These results strongly suggest that the pandemic of egg-associated human salmonellosis that came into prominence in the 1980s is primarily an example of bacterial adaptive radiation that affects the safety of the food supply.

The genus name *Salmonella* was first suggested by Lignieres in 1900 in recognition of the work carried out by the American bacteriologist, D.E. Salmon, who in 1886, described the hog cholera bacillus (D'Aoust, 1989; Topley and Wilson, 1929a). In 1888, Gaertner isolated *Bacterium enteritidis* (later renamed *S. enteritidis*) from both the meat of an emergency slaughtered cow and the organs of a man who was one of 58 people who consumed the meat and developed food poisoning. The man, who died, had eaten about 1.5 lb of the meat and died in 36 hours. This is probably the first laboratory-confirmed outbreak of salmonellosis (Topley and Wilson, 1929b). By the 1960s, the name *Salmonella* was widely accepted to delineate a specific genus of the family Enterobacteriaceae and it was included in the *Approved Lists of Bacterial Names* published in 1980 (Old, 1992).

In developed countries, normally healthy individuals recover from salmonellosis (mild to moderate gastroenteritis) with supportive treatment including fluid and electrolyte replacement and without recourse to antibiotics. Deaths resulting from salmonellosis in outbreaks are rare, but do occur. Use of antibiotics in these cases can increase the time during which the organism is excreted and so is not a recommended approach to treatment (Old and Threlfall, 1998).

The serotypes of *Salmonella* responsible for most cases of reported salmonellosis do change over the years. Until the mid-1980s, *S. typhimurium* was the most commonly reported serotype in the USA and UK, but *S. enteritidis* has overtaken *S. typhimurium* in more recent years due to a large rise, particularly in egg-related outbreaks and incidents of salmonellosis involving *S. enteritidis* PT4. From time to time, reported cases involving different serotypes and/or phage types show an increase then decline, and careful epidemiological study is able to indicate sources, e.g. *S. enteritidis* PY6 became the second most commonly reported phage type of *S. enteritidis* in the UK in 1997 being responsible for over 1600 cases (Bell and Kyriakides, 2002).

The primary sources of *Salmonella* are the gastrointestinal tract of humans, domestic and wild animals, birds and rodents. Consequently, they are widespread in the natural environment including soil and waters in which they do not usually multiply significantly but may survive for long periods, i.e. many months in soil and dried animal faeces. Transmission routes to humans are mainly between humans, from animals via the food supply and from water and the environment. Foods contaminated by *Salmonella* usually look and smell normal. On occasion, multiple serotypes of *Salmonella* have been found associated with raw food materials implicated in outbreaks, e.g. 11 strains were identified in paprika powder including *S. saintpaul*, *S. javiana*, *S. rubislaw*, *S. florian*, *S. loenga* and six un-named strains (Lehmacher *et al.*, 1995).

Poultry and egg products have been recognised as a source of *Salmonella*, e.g. 18 out of 23 flocks of poultry investigated in Denmark were found to be positive for *Salmonella* and seven different serotypes were isolated during the investigation (Skov *et al.*, 1999). Other studies have shown that multi-antibiotic resistant *S. typhimurium* DT104 can also be found in poultry and the poultry growing environment (Rajashekara *et al.*, 2000). In October 1996, 37 people (seven adults and 30 children) attended a birthday party in north London, England. Within 24 hours, 30 people developed symptoms of gastroenteritis; illness lasted between two and three days (Dodhia *et al.*, 1998). The children were mainly 4–5 years of age and one child was admitted to hospital due to dehydration. The implicated food vehicle was ice cream which was the only home-made food item consumed

at the party. A family outbreak of salmonellosis occurred in England (Morgan *et al*., 1994) due to the consumption of home-made ice cream. The ice cream had been made from raw eggs and analysis of the ice cream found it to contain *S. enteritidis* at levels of 10^5 cfu/g. A further outbreak was reported in Florida, USA, in 1993 (Buckner *et al*., 1994) where 12 out of 14 people suffered from salmonellosis, 7–21 hours after eating food at a 'cookout' at a psychiatric treatment hospital in Jacksonville. *S. enteritidis* PT13A was isolated from the three stool samples obtained from affected individuals. The same strain was also isolated from ice cream which had been prepared using raw eggs, three hours before the meal (Hennessy *et al*., 1996).

The use of potentially contaminated ingredients such as raw shell eggs in the preparation of uncooked foods such as ice cream or dairy-based desserts is commonplace. Eggs are a well-known hazard in relation to *Salmonella* and the organism may be present both on the outer surface and in the contents of the egg. The incidence of *Salmonella* in egg does vary but in the UK has been reported to range from 1 in every 650 eggs (de Louvois, 1993) to 1 in 2900 (de Louvois, 1994). Refrigeration of eggs after purchase can significantly reduce the colonisation and subsequent growth of *Salmonella* in the egg contents.

The temperature conditions allowing growth of *Salmonella* and for destroying the organism in foods of differing formulation have been the subject of research for over 100 years. In 1904, it was reported that *Salmonella typhi*, *S. paratyphi* and *S. enteritidis* 'were all killed when the milk was heated to 59°C if 10 minutes was taken to heat the milk to that temperature' (Savage, 1912). *Salmonella* is probably the most researched of the foodborne pathogens due to its recognition in food poisoning outbreaks that have occurred over many decades. There are few foods that have not been implicated in outbreaks of salmonellosis and examination of these outbreaks can provide valuable information regarding the factors important for controlling the organism. It is usually a failure in food production/manufacturing control systems that allows the organism to gain entry and/or survive to cause an outbreak of illness. Many such failures occur in the control of very basic areas such as cross-contamination, cooking processes, personal hygiene and food storage temperature (Bell and Kyriakides, 2002).

Contamination sources at egg-packing stations are somewhat less problematic to solve than those on poultry processing lines. Eggs are received and stored in warehouses where the trays of eggs are deboxed then usually automatically sorted into sizes and candled to check for cracks and spoilage prior to packing. The biggest sources of cross-contamination in egg-packing houses are any systems that come into direct contact with the eggs themselves. Therefore, egg brushes (if used) or any cups used for picking the egg up or indeed supporting the egg are some of the key areas where contaminants can be spread to subsequent eggs. In order to prevent the entry of any *Salmonella* from the shell surface into the egg, UK-produced eggs are kept dry and control of surface dirt and debris is by visual inspection and removal of soiled eggs instead of washing. Disinfectant treatment of eggs does not destroy bacteria that have already penetrated the shell; however, mild heat treatment of whole shell eggs to eliminate any *Salmonella* that may be on the shell or within the egg contents is possible (Hou *et al*., 1996), but conditions of treatment have to be finely controlled to prevent the egg from starting to cook, thus changing the raw egg quality for culinary use.

Fluctuations in temperature need to be avoided during storage and transportation due to the potential for such fluctuations to allow condensation to build up on the egg, again aiding the ingress of the microorganisms, if present, from the outside to the inside of the egg. Storage and transportation temperatures should be maintained below 20°C to reduce the opportunity for any contaminants that have entered the egg to elevate in number during the shelf life of the egg. These and other recommendations relating to safe-handling practices for eggs were made by the Advisory Committee on the Microbiological Safety of Food (1993) in its report on eggs.

Three different strains of *Escherichia coli* O157:H7 inoculated into mayonnaise at levels of approximately 10^7 cfu/g rapidly died off when stored at 25°C but cells were still detectable in mayonnaise up to 35 days when held at 7°C (Weagant *et al*., 1994). The examples of food-associated outbreaks of illness caused by microorganisms are given in Table 6.1.

Hope *et al*. (2002) summarised a quantitative microbial risk assessment designed to characterise the public health impact of consumption of shell eggs and egg products contaminated with *S. enteritidis*. The risk assessment model had five modules. The Egg Production module estimated the number of eggs produced that are SE-contaminated. Shell Egg Processing, Egg Products Processing, and Preparation and Consumption modules estimated the increase or decrease in the numbers of SE organisms in eggs or egg products as they pass through storage, transportation, processing and preparation. A Public Health Outcomes module then calculated the incidence of illnesses and four clinical outcomes, as well as the cases of reactive arthritis associated with SE infection following consumption. The baseline model estimated an average production

Table 6.1 Examples of food-associated outbreaks of illness caused by micro-organisms.

Food	Country	Micro-organism	Incidence	Reference
Mayonnaise	UK	*Salmonella typhimurium* DT49	76	Mitchell *et al.* (1989)
Custard in bakery goods	UK	*Salmonella enteritidis* PT4	17	Barnes and Edwards (1992)
Ice cream	USA	*Salmonella enteritidis*	224,000	Hennessy *et al.* (1996)
Marshmallows	UK	*Salmonella enteritidis* PT4	24	Lewis *et al.* (1996)
Egg fried rice	Ireland	*Salmonella enteritidis* PT4	110	Cronin (1999)
Mayonnaise	Denmark	*Salmonella enteritidis*	10,000	ICMSF (1980)
Curried turkey mayonnaise	UK	*Escherichia coli*	27	Riordan *et al.* (1985)

of 2.3 million SE-contaminated shell eggs per year of the estimated 69 billion produced annually and predicts an average of 661,633 human illnesses per year from consumption of these eggs. The model estimated that approximately 94% of these cases recovered without medical care, 5% visited a physician, an additional 0.5% was hospitalised and 0.05% resulted in death. The contribution of SE from commercially pasteurised egg products was estimated to be negligible. Five mitigation scenarios were selected for comparison of their individual and combined effects on the number of human illnesses. Results suggested that mitigation in only one segment of the farm-to-table continuum will be less effective than several applied in different segments. Key data gaps and areas for future research include the epidemiology of SE on farms, the bacteriology of SE in eggs, human behaviour in food handling and preparation, and human responses to SE exposure.

The experiments reported by Cogan *et al.* (2001) have shown that artificially large numbers of *Salmonella* cells inoculated into the egg, or the addition of growth promoting diluents, substantially alter the growth profiles of the bacteria within the egg. The low level of growth seen in these experiments when using low numbers of cells in low nutrient, low iron diluents are comparable with those seen with naturally contaminated eggs. The development of this realistic model of natural *Salmonella* contamination of the egg makes it possible to examine the effects which storage time and temperature, both important factors in ensuring food safety, have on the proliferation of *Salmonella* in the egg, and to apply these accurate data to risk assessments of storage conditions.

Growth profiles of two isolates of *S. enteritidis* phage-type PT4 inoculated either into the albumen of whole shell eggs or into separated albumen were found to be markedly affected by the size of the inocula and the composition of the medium used to suspend the cells prior to inoculation. Using this model with an inoculum of two cells, growth of *Salmonella* was not reported in 93% of eggs held at 20°C for eight days. In approximately 7% of eggs, however, growth occurred during the eight days of storage. High levels of growth were also reported more frequently if the inoculum was suspended in buffered peptone water or maximal recovery diluent rather than in phosphate-buffered saline (Cogan *et al.*, 2001).

FSIS completed an updated risk assessment to examine the effect of pasteurisation and refrigeration on reducing human illnesses from *S. enteritidis* in shell eggs (Schroeder *et al.*, 2006). The risk assessment model was written in Visual Basic for applications (Microsoft, Redmond, WA) and run using Monte Carlo methods. The model estimated that if all shell eggs produced in the USA were pasteurised for a 3-$\log_{10}$ reduction of *S. enteritidis*, the annual number of illnesses from *S. enteritidis* in eggs would decrease from approximately 130,000 to 40,000. Pasteurisation for a 5-$\log_{10}$ reduction of *S. enteritidis* was estimated to reduce the annual number of illnesses to 19,000. The model also estimated that if all eggs produced in the USA were stored and held at 7.2°C within 12 hours of lay, the annual number of illnesses from *S. enteritidis* in eggs would decrease from 130,000 to 28,000. As a result, rapid cooling and pasteurisation of shell eggs were predicted to be highly effective mitigations for reducing illnesses from consumption of *S. enteritidis* in shell eggs.

Apart from being a significant vehicle of human salmonellosis, poultry also remains a vehicle of other important pathogens such as *Campylobacters*, *Listerias*, various *Enterobacteriaceae*, fungi-like *Aspergilli* and parasites such as *Cryptosporidia*. Among the available methods for the control of these pathogens, the one most widely practiced is the use of various

antimicrobials such as antibiotics, fungicides and coccidioides in the birds' diet (Irwin *et al*., 1993).

Papadopoulou *et al*. (1997) studied the putative transfer of antibiotic resistance from poultry to humans, by examining hens' eggs for the presence of various pathogens. *Staphylococcus*, *Enterobacter*, *Escherichia*, *Proteus* and *Pseudomonas* spp. were the most frequently isolated genera. Sensitivity tests, performed with the Kirby-Bauer technique, showed the presence of resistant strains of *Staphylococcus aureus*, *Enterococcus*, *E. coli*, *Enterobacter cloacae*, *Pseudomonas stutzeri* and *Citrobacter freundii*.

The transfer of oxytetracycline was studied by Donoghue and Hairston (2000) to get an insight whether it would enter the egg albumen during the latter two phases of albumen formation. Oxytetracycline was transferred into albumen during both phases of albumen formation. Therefore, it was concluded that drugs may transfer into egg whites during the latter phases of formation prior to oviposition. Therefore, poultry producers or veterinary practitioners dosing laying hens must consider that egg whites contained in the first egg lay after dosing may contain drug residues.

A number of experiments have been carried out using irradiation in eggs. For example, eggs inoculated with the colonies of *S. enteritidis* were irradiated and the effect of radiation on the population of bacteria was investigated together with the determination of the physical characteristics of the irradiated eggs. The occurrence of *S. enteritidis* in both the shell and the internal membrane of the egg significantly decreased at a dose as low as 1 kGy.

Eggs from laying hens were irradiated using radioactive Co^{60} at a dose of 1, 2.5 and 5 kGy. Parameters describing the colour of egg yolk, such as L (lightness), a (redness) and b (yellowness), were determined with HunterLab chromatometer. The levels of all three parameters dropped upon ionising radiation. While at a dose of 1 kGy, the difference in the parameters was not statistically conclusive, after irradiation using doses of 2.5 and 5 kGy, the levels of the parameters L*, a* and b* showed a statistically conclusive decrease which was also accompanied with changes in sensorial properties such as complete or partial decolouration (Dvorak *et al*., 2005).

Food irradiation is an alternative to free *Salmonella* spp. and *Campylobacter* spp. eggs, as a low-dose point to a safety assurance. Pinto *et al*. (2004) presented the correlation between irradiation doses (0.5 kGy up to 5 kGy at dose rate of 1.0 kGy/hour) and some of functional and nutritional egg properties. Viscosimetry of non-irradiated and irradiated eggs was evaluated by means of VT550 Haake with an NV sensor and coaxes cylinders. After irradiation at 5 kGy, the yolk colour died (pale yellow) and the white egg was turned into turbid yellow. The cross equation (Christoffel, 2005) was applied to viscometer curves. Irradiation effects on nutritional properties were evaluated by means of polyacrylamide gel electrophoresis of the egg proteins. Lipids were identified by TLC. Based on these results the sanitation dose was shown to be lower than the limit dose for the decrease of the main egg properties.

Verde *et al*. (2004) developed the application of irradiation technology to chicken eggs in order to get a product free of pathogenic micro-organisms. Results showed that low-irradiation doses could guarantee egg sanitation.

A previous study by Serrano *et al*. (1997) concluded that the minimal dose of 0.5 kGy would be sufficient to eliminate *S. enteritidis* from the surface of whole eggs, and a dose of 1.5 kGy would be sufficient to eliminate the organism from whole shell eggs without significant adverse effects on the egg quality, taking in account that the number of *S. enteritidis* in naturally contaminated eggs do not normally exceed 10–100 cfu/mL. Irradiation of egg products has been used experimentally as an alternative to heat pasteurisation and to eliminate *Salmonella* in frozen liquid egg products (Wong *et al*., 1996). However, there has been a gradual shift from frozen liquid egg products to egg products for immediate consumption because of lower cost energy and consumer demand for egg availability.

Considering the application of a minimal radiation dose of 1.5 kGy and based on the results obtained, a population reduction of 5 log for *S. typhimurium*, 7 log for *S. enteritidis* and *C. coli*, 16 log for *Campylobacter jejuni*, and an inactivation of at least 90% (1 log) for natural egg contaminants is expected. In this way, a radiation dose of 1.5 kGy is suggested by Verde *et al*. (2004).

Food pasteurised by high pressure at moderate temperature has already been marketed in several countries, principally Japan. There is great interest in this method in Europe and USA, due to the great demand minimally processed high-quality foods. Flavour components and vitamins remain unaffected because covalently bonded molecules are generally not modified. While the influence of temperature on food has been extensively investigated, effects of pressure, also in combination with temperature, have been increasingly attracting scientific attention in recent years (Tauscher, 1994). High-pressure processing has advantages over other more conventional methods: instantaneous and homogeneous effect of pressure throughout the food which remains essentially raw due to mild temperatures (Farkas, 1986).

Through high-pressure treatment, egg products have the possibility of improved microbiological quality with only negligible effects on functional properties. Such treatment allows for the absence of chemical additives (Ponce *et al*., 1995); however, it is important to know the effect of high-pressure treatment on pathogens in each specific product.

Ponce *et al*. (1999) examined the potential for inactivation of *S. enteritidis* (from food origin) inoculated in liquid whole egg using high hydrostatic pressure–temperature–time combinations, to observe for the presence of injured cells and, consequently, to evaluate the process as a possible alternative to heat pasteurisation.

The inactivation rate increased with pressure and exposure time, being minimal at 350 MPa and –15°C for five minutes (over 1 $\log_{10}$ of reduction) and reaching total inactivation (8 $\log_{10}$ of reduction) in several treatments at 50°C. Treatments in cycles showed greater effectiveness than continuous treatments of the same total time. The effect of pressure was enhanced by elevated temperatures. The higher counts were obtained in the non-selective medium, indicating the presence of injured cells after pressure treatment.

Badr (2006) tried to improve the microbial safety of liquid egg white (LEW) and yolk by gamma irradiation at room temperature and studying the changes in their chemical and organoleptic properties due to gamma irradiation at room temperature followed by cold storage at 4 ± 1°C, and to determine the effects of irradiation on amino acid composition of egg white and yolk and fatty acid profiles of egg yolk lipids.

The results showed that gamma irradiation and refrigerated storage had no significant effects on proximate composition and pH of liquid egg samples, while significantly decreased the contents of total carotenoids in liquid egg yolk (LEY) samples. Furthermore, gamma irradiation had no significant effects on protein solubility and the contents of free SH in LEW, while induced significant slight decreases in protein solubility and the contents of free SH in LEY. Cold storage, however, showed no significant effects on protein solubility and free SH in all liquid egg samples. FFA contents and PV of LEY lipids significantly increased post-irradiation treatments and during storage, but the observed values were relatively low and acceptable. In addition, gamma irradiation at 3-kGy dose had no significant effects either on the amino acid composition of LEW and LEY or on fatty acid profiles of LEY lipids. The sensory preference was altered neither for the liquid egg samples nor for scrambled egg samples that were prepared from irradiated liquid egg products. Finally, gamma irradiation at 3-kGy dose appeared to be the optimum for treating LEW and LEY at room temperature followed by cold storage at 4 ± 1°C.

A research project was conducted by Jones and Musgrove (2005) to determine what role the shell strength might play in affecting external *S. enteritidis* contamination of egg contents. Visibly clean eggs were collected from an in-line shell egg-processing facility at the accumulator. Eggs were inoculated by dipping in a concentrated suspension of nalidixic acid-resistant *S. enteritidis*. After storage, eggs were assessed for shell strength and both external and internal *S. enteritidis* contamination. In the first study, there was a significant difference ($p < 0.05$) in shell strength among the three replicates. No differences between treatments were found for shell strength or *S. enteritidis* contamination of contents. In the second study, there were no replicate differences for any of the monitored factors. When rinsate and content samples were enriched, 100% of the rinsates were positive for *S. enteritidis*. No content samples were shown to be contaminated with *S. enteritidis* during direct plating, but 3–5% of the samples from each replicate were positive after enrichment. Correlation analysis of the results from each study found only weak correlations between shell strength and *S. enteritidis* contamination on eggshell surface or contents. Within the range of shell strengths recorded in this study, the correlation analysis suggests that shell strength does not play a major role in *S. enteritidis* contamination. *S. enteritidis* has a higher ability to colonise the vaginal epithelium than other serovars, and the *Salmonella* LPS-type may play an essential role in tropism of the reproductive tract (Mizumoto *et al*., 2005).

Tests for detection of antibody in eggs have been developed and used before. The existing tests are often based on enzyme-linked immunosorbent assays (ELISA) using different (combinations of) antigenic components of *Salmonella* spp. (Holt *et al*., 2000; Skov *et al*., 2002). Recently, the possible suitability of biosensors for the detection of humoral response has been recognised (Bergwerff and van Knapen, 2003, 2006). A biosensor consists of a reusable immobilised biological ligand that 'senses' the analyte, and a physical transducer, which translates this phenomenon into an electronic signal (Jongerius-Gortemaker *et al*., 2002). The use of biosensors promises the possibility of high-throughput analyses, and also the detection of multiple serovars or serogroups within a family of infectious disease agents – or antibodies against these agents – in a single run.

A surface plasmon resonance (SPR) biosensor assay was developed by Thomas *et al*. (2006) on the

basis of a LPS antigen of *S. enterica* serovar *enteritidis* to detect egg yolk antibodies against *S. enterica* serovar *enteritidis*. This biosensor assay was compared to two commercial ELISA kits based on LPS antigen and flagellar antigen. A number of 163 egg yolk and combined egg white and yolk samples from chickens experimentally infected with *S. enterica* serovar *enteritidis* and 90 egg yolk and combined egg white and yolk samples from uninfected chickens were analysed.

Receiver operating characteristic analysis of the data calculated a diagnostic sensitivity of 82% and a diagnostic specificity of 100%. The within-day coefficient of variation of a positive internal-control egg yolk was 1%. The SPR biosensor assay was able to detect antibodies in a significantly higher percentage of known positive samples than the commercial ELISA's. The anticipated use of the SPR biosensor assay is to determine the *S. enterica* serovar *enteritidis* serostatus of non-vaccinated layer hens.

It is generally accepted that fatty food intake constitutes a predominant exposure route for polychlorinated dibenzo-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), polychlorinated biphenyls (PCBs), organochlorinated pesticides (OCPs) and other persistent organic pollutants. On the other hand, the general population is also exposed to heavy metals both through food intake as well as inhalation.

The total toxic equivalent quantity (TEQ) levels for dioxins and dioxin-like PCBs in commercially available eggs sampled in several European countries range from 0.69 to 2.76 pg TEQ/g egg fat (Gallani *et al.*, 2004; Hamm *et al.*, 2005). For free-range hens that forage on soil, higher levels up to 88 pg PCDD/F World Health Organization (WHO)-TEQ/g fat were observed at different occasions. These elevated values have been linked to environmental parameters, e.g. incinerator ash-contaminated soils, wood shavings in chicken litter, contaminated environmental feed ingredients such as ball clay and kaolin, and the proximity of chemical plants (Diletti *et al.*, 2005; Pirard *et al.*, 2005).

Van Overmeire *et al.* (2006) found that eggs from private owners were more contaminated than eggs from commercial farms. The ratios of levels in eggs from private owners to the levels in eggs from commercial farms ranged from two to eight for the toxic contaminants lead, mercury, thallium, dioxins, polychlorinated biphenyls and the DDT group. DDT contamination was marked by the substantial presence of p,p′-DDT in eggs from private owners in addition to dichlorodiphenyldichloroethylene (p,p-DDE) and dichlorodiphenyldichloroethane (p,p′-DDD). It is postulated that environmental pollution is at the origin of the higher contamination of eggs from private owners. Extensive consumption of eggs from private owners is likely to result in TEQ intake levels exceeding the tolerable weekly intake.

Pussemier *et al.* (2004) determined dioxin levels in eggs from free-range hens owned by private owners in the northern districts of Antwerp. The reasons for this survey stem from some fears that free-range eggs could be contaminated by local environmental sources (e.g. soil, grass, earthworms) as a result of the presence in this area of intensive industrial and domestic activities. The analyses revealed high levels of PCDD/F in the home-produced eggs (average = 9.9 pg WHO-TEQ/g of fat; $n = 15$). An evaluation of the available results, carried out by the Scientific Committee of the Belgian Federal Agency for the safety of the food chain, showed that the analysis of congener profiles was of limited use because all profiles were dominated by the OCDD congener, independently of the level of contamination. There were not enough indications allowing a causal link to be established between high dioxin levels in eggs and soil contamination and, on the other hand, it was assumed that other factors such as feeding habits, physiological state and egg-laying rhythm of the hens could not be ruled out as potential causes of aggravation.

Very few studies have been carried out on transfer of dioxins and related compounds from commercial feed to hens. Pirard and De Pauw (2006) continued a preliminary study on dioxin transfer in laying chickens. Only 2,3,7,8-congeners were found in all organs studied, and these latter showed the same congener profile and similar lipid-normalised concentration, except for the liver. Abdominal fat and liver seemed to be the major storage sites and the liver preferentially retained highly chlorinated congeners. Unfortunately in this previous trial, the laying process stopped very early for unknown reasons leading to a considerable loss of information. Pirard and De Pauw (2006) investigated a more complete gastrointestinal absorption, excretion in eggs and bioaccumulation of dioxins in different tissues in chickens fed for 14 weeks with a 9-ng TEQ/kg contaminated feed. Stable levels were reached after seven weeks in excreta and nine weeks in eggs. Lipid-adjusted concentrations and patterns were unexpectedly similar in the abdominal fat and the liver. On the contrary, eggs and breast muscles showed a different pattern with a higher level for high chlorinated congeners. When extrapolating their results, they found that a feed containing 0.750 ng TEQ/kg of dioxins (European norm for feedstuff) would cause a level lower than the maximum threshold level of 3 pg TEQ/g fat for chicken eggs fixed by European Communities (Council Regulation No. 2375/2001).

Kan and Meijer (2007) reviewed the information on carry-over of toxic substances from feed to food of animal origin (meat, organs, milk and eggs). This update is necessary and essential as exposure levels have dropped considerably and analytical as well as toxicological techniques have become much more sensitive.

The data on carry-over percentage (amount excreted per day via milk or eggs or deposited in the animal/amount ingested per day on a percentage basis) or concentration ratio (concentration in product/concentration in feed) as well as half-life of these compounds (if reported or to be deduced) are summarised. Hsu *et al.* (1995) recovered a maximum of 0.14% of intake via the eggs and depletion of residues from the body was rapid. Schenck and Donoghue (2000) obtained similar results in a study with laying hens. Kan (1978) reviewed available carry-over data for DDT from feed to poultry and eggs. Concentration ratios (level in fat/level in feed) from feed to fat were lower in high-producing laying hens than in meat-type broiler breeder stock. The excretion of DDT by eggs was probably responsible for this difference, as a higher laying percentage seemed to result in a lower concentration ratio. Carry-over of DDT from feed to egg was similar to carry-over to body fat, but was also influenced by laying percentage. Thus, accumulation of DDT and DDE is considerable and half-life of residues is estimated to be seven weeks or more.

Hoogenboom *et al.* (2006) fed diets with five different levels of dioxins up to 2.04 ng TEQ/kg to laying hens for eight weeks. Carry-over percentages from feed to egg ranged from five to 48% with a tendency to lower carry-over for the highly chlorinated congeners. Cadmium accumulates mainly in the liver and kidneys (Prankel *et al.*, 2004). Carry-over to milk is very low or absent (<0.05%; Bluthgen, 2000). The same is true for carry-over to meat and eggs. Muscle, milk and eggs contain much lower ochratoxin levels when the animals are exposed to this mycotoxin (EFSA, 2004).

Systems such as GMP for feed production and GAP at the farm should ensure that adequate precautions are taken. The reported incidence of coccidiostat residues in eggs in the European Union (EU) in 2003 (SANCO/2810/2004) does, however, indicate that good control has not yet been achieved. Kan and Petz (2000) have reviewed several trials in which veterinary drugs or feed additives have been administered to laying hens. Nearly all veterinary drugs and feed additives available on the market and tested may result in residues in eggs, thus inadequate control of contamination of feed may result in residues in eggs exceeding legal limits. As MRL values are not set for non-target animals (thus a 'zero' tolerance), any drug not licensed for use in layers if detected in eggs, will constitute a violation of legal limits.

Pasteurised egg product can be contaminated because of:

- An incorrect pasteurisation process.
- The pasteurisation process being insufficient due to the large bacterial loading of the raw egg pulp. High bacterial loads arise because raw egg pulp is not stored under refrigerated conditions.
- Cross-contamination from raw pulp to pasteurised pulp. Cross-contamination could occur via staff, equipment, utensils etc.

Outbreaks of *Salmonella* food poisoning associated with eggs have been traced to:

- Use of raw eggs, for example, in mayonnaise, eggnogs or gelati.
- Eggs undergoing only a mild cooking process, for example, in hollandaise sauce or soft boiled eggs.
- Cross-contamination, for example, in bakeries where uncooked product (such as imitation cream) has been prepared using utensils used for uncooked egg mix.
- Unhygienic methods of production of shell eggs (Australian Egg Corporation Limited, 2005a).

C. jejuni is the leading cause of bacterial foodborne illnesses in the USA and other developed countries (Friedman *et al.*, 2000). The vast majority of human campylobacteriosis cases occur sporadically, and primarily result from consumption of undercooked poultry or other foods cross-contaminated with raw poultry meat during food preparation (Friedman *et al.*, 2000).

There has been a major debate on whether vertical or horizontal transmission is responsible for the introduction of *Campylobacter* into chicken flocks. For years, the prevailing theory has been that horizontal transmission from the environment is the major source of *C. jejuni* infection for broiler flocks, and that vertical (eggborne) transmission is unlikely. Vertical transmission of *C. jejuni* is still questionable because live *Campylobacter* have not been detected in the content of commercial breeder eggs, young hatchlings or hatcheries under natural conditions (Chuma *et al.*, 1994; Hiett *et al.*, 2002; Kazwala *et al.*, 1990).

Sahin *et al.* (2003) evaluated the importance of vertical transmission via eggs as a source of flock infection by *C. jejuni* on broiler farms. To this end, the ability of *C. jejuni* to penetrate eggshells and to survive in different compartments of the egg was determined. More importantly, prevalence of the organism in eggs obtained from multiple broiler flocks, hatchery- and

laboratory-infected hens was determined using both culture and PCR methods. They found that vertical transmission of *C. jejuni* through the egg is probably a rare event and does not play a major role in the introduction of *Campylobacter* to chicken flocks.

Veterinary drugs and feed additives (especially some coccidiostats) can be absorbed by the digestive tract of laying hens and transferred to the egg. Physicochemical characteristics of these compounds determine their pharmacokinetic behaviour and distribution to and within the egg. Traditionally, the quite lipid-soluble drugs and additives are expected to yield residues only in the fat-rich yolk.

However, the quite lipid-soluble drug doxycycline, as well as many other drugs, showed during long-term administration higher residues in white than in yolk. In a model study with 11 sulfonamides differing in pK_a value and lipid solubility, their distribution *in vivo* between yolk and white was determined by Kan and Petz (2000). Neither differences in pK_a values nor those in lipid solubility could explain the distributions found. Binding to egg white macromolecules *in vivo* as an explanatory factor was tested with five sulphonamides, and no correlation between binding and the distribution of sulphonamides between white and yolk was found. Literature data on the distribution of drugs between egg white and yolk showed a reasonable consistency within drugs and a large variability among drugs (as could be expected). This larger database also did not provide a clue as to what factor determines the distribution of a drug between egg white and yolk when given to laying hens.

Prediction models for residue transfer into eggs are being developed. Recent results by Donoghue and Myers (2000) indicate that the developing egg yolk serves as an important storage depot for chemical residues. The current study was conducted to visualise incorporation and potential compartmentalisation of drug residues in developing egg yolks. To this end, the drug magnevist was injected into hens to evaluate drug transfer into either early- or late-developing yolks. High-resolution magnetic resonance images of drug residues in eggs were acquired using a 1.5 T Siemens Magnetom clinical scanner. These results have significant human food safety implications because even after only a single dose, sequestered drug residues may be stored and later released to contaminate eggs for days to weeks after dosing.

6.1.1 Eggs and diet

Eggs can be used as boiled or fried or as powder (dried). Their widest use is in cooking and pastry making, because egg has the richest food value and in combination with milk can provide all necessary ingredients for full nutrition (Kardoulis, 2003).

Eggs are very low in fat, contain good cholesterol (HDL) and are rich in vitamins, calcium, phosphorous, iron, sodium, potassium and a range of high-quality proteins. Egg lipids are confined to the yolk and account for about 30% of the fresh weight of yolk and for 60% of the yolk dry matter (Leskanish and Noble, 1997). The fatty acid composition of egg lipids in laying hens can be influenced predictably by the fatty acid composition of the diet (Beynen, 2005). The liver of the layer hen produces most of the lipids found in egg yolk, the lipids being transported to the ovary by serum lipoproteins (Elkin, 1997).

Laying hens were fed diets with or without 10 or 30 g of the whole seed of black cumin (*Nigella sativa*) per kg (El Bagir *et al.*, 2006). The concentrations of total lipids, total cholesterol, phospholipids and triacylglycerols in serum and egg yolk were measured. Feeding with 1 and 3% black cumin seeds for a period of three months reduced egg yolk total cholesterol by 34 and 42%, respectively. Serum cholesterol concentrations averaged for the whole feeding period were lowered by 15 and 23% after feeding with 1 and 3% black cumin seeds, respectively. Black cumin seeds in the diet of laying hens also caused a lowering of serum and egg yolk concentrations of triacylglycerols and phospholipids. It is concluded that black cumin seeds and/or the active principle are of interest as potential egg yolk cholesterol-lowering agents.

The major solid constituents of the albumen are proteins (75% ovalbumin, 3% ovoconalbumin and 2% ovoglobulin) and glycoproteins (13% ovomucoid and 7% ovomucin), some of which possess antimicrobial activity. The most abundant albumen minerals are sulphur, potassium, sodium and chloride. Other minerals such as phosphorous, calcium and magnesium are present in lesser amounts along with some traces of iron (Romanoff, 1967).

The egg is one of the most appreciable sources of proteins of high biological value, vitamins and trace elements. Their consumption is reduced because of their high cholesterol content (175 to 220 mg/100 g).

6.1.2 Egg quality

The classification of eggs into products with different qualities happens when the eggs are subjected to sizing in special packing centres. The eggs are categorised in two qualitative grades A and B.

Quality of eggs is primarily related to shell stability and resistance, and to chemical composition (Pingel and Jeroch, 1997). Since 1995, selective breeding programmes led to a significant increase in layers'

Table 6.2 Categorisation of eggs based on their weight.

Category	Weight of eggs
1st	Up to 70 g
2nd	From 65 up to 69 g
3rd	From 60 up to 64 g
4th	From 55 up to 59 g
5th	From 50 up to 54 g
6th	From 45 up to 49 g
7th	Down to 45 g

production efficiency; the same is not true for traits defining eggs' quality (shell colour and resistance, yolk percentage, resistance to breaking, presence of blood spots).

The layers' nutrition and husbandry system significantly influence the sensory characteristics and the chemical composition of eggs; lipid concentration and chemical characteristics are particularly influenced by the lipid composition of the diet (Terned and Leitsch, 1997). The use of fish oil in the diet can significantly influence the fatty acid composition of yolk, leading to an increase in long-chain fatty acids (Nardone and Valfre, 1999).

Three feeding experiments were conducted by Parpinello *et al.* (2006) adding either palm butter, grape seed oil, flax seed oil, *n*–3 polyunsaturated fatty acids (PUFA) such as flax seed and marine algae and the natural antioxidant rosemary to the hens' diet. For each experiment, a standard diet was used as control. The results suggested that vegetable lipids (palm butter, grape seed, flax seed), *n*–3 PUFA (flax seed and marine algae) and rosemary may be used in the diet of hens without affecting the sensory properties of eggs. The sensory quality of eggs was evaluated using hard boiled, scrambled eggs and Madeira cake.

Table 6.2 outlines the categorisation of eggs based on their weight. The characteristics of eggs and their categorisation are given in Table 6.3. The packaging of final products is summarised in Table 6.4.

6.1.3 Product use

With regard to food safety and hygiene of eggs, they have a shelf life of 28 days from the date of candling–packaging. After sale in supermarket, they could be maintained in the fridge.

In general, eggs could be used by all the consumers. The product labels refer to the following:

- expiry date
- instructions for storage and use of eggs.

One of the products made by eggs is mayonnaise. A formula to estimate pH of a mayonnaise recipe has

Table 6.3 Characteristics of eggs and their categorisation.

Characteristics	Category A	Category extra A	Category B	Category C
Height of air chamber	≤ 6 mm	≤ 4 mm	≤ 9 mm	Non-conforming eggs of categories A and B
Shell-membrane condition	Normal, clean, intact, with shiny shell	Similar to category A	Normal, clean, intact, with shiny shell	
Egg white appearance	Egg white clean, transparent, of gelatin composition, no foreign matter		Egg white clean, transparent, no foreign matter	
Yolk appearance	Egg yolk visible in the form of shadow, no visible perimeter, not far away from the egg centre in case of rotation, no foreign matter of any kind Colour = 10–13 x/degrees in Roche scale		Egg yolk visible in the form of shadow, no visible perimeter, not far away from the egg centre in case of rotation, no foreign matter of any kind Colour = 10–13 x/degrees in Roche scale	
Presence of genital cell	Absence of genital cell		Absence of genital cell	
Odour	No foreign odours		No foreign odours	

Table 6.4 Packaging of final products.

Unit packaging	• Paper boxes of 30 pieces • Plastic or paper boxes with 4, 6 or 10 eggs
Group packaging	• Cartons of 6, 10, 12 paper boxes • Cartons of 28, 30, 60 paper boxes • Cartons of 25, 45, 50, 60 plastic boxes
Packaging for storage/distribution	• Wooden pallets of dimensions 1 m × 1.20 m • European wooden pallets of dimensions 1 m × 0.80 m (in some cases wrapping of the products using cellophane)

been proposed and validated (Xiong *et al*., 2000). By using the validated formula and a safe pH value (4.10 or 4.00) for mayonnaise, it is concluded that a mayonnaise recipe is safe only if its ratio of egg to vinegar is equal to or less than its safe ratio. To make safe mayonnaise in the kitchen, it is recommended that at least 20 mL vinegar (6% w/v acetic acid) per fresh egg yolk, 40 mL per fresh egg white or 60 mL per fresh whole egg should be used. After preparation, the product should be held at 20°C or above for at least 48 hours before refrigeration or consumption.

6.1.4 Labelling of eggs

Labelling of eggs should be carried out by the producer, the classification label should state the quality, the category of weight and the method (Free-Range Barn, Battery etc.) of production. Date of visual inspection is not required by the relative provision of EU legislation. However, in hot climates as in Greece, it is essential (Kardoulis, 2003). The data shown on the label are given in Table 6.5.

6.1.5 Market criteria

Eggs that carry on their packing the date laid are preferred.

6.1.6 Egg manufacturing

Chickens are raised mainly for meat production and hens for reproduction. In the last ten years, the number of chickens raised for meat production and egg production chickens increased.

Table 6.5 The data on the label of an egg package.

- Quality category
- Product description
- Weight category
- Number of eggs
- Company details
- Number of the visual selection centre of the company
- Product bar code
- Lot number
- Instructions for use by the consumer
- Date of visual selection
- Use by date

The analysis of hazards is given in Table 6.6. The determination of critical control points (CCPs) is summarised in Table 6.7 and the ISO 22000 analysis worksheet for the determination of PRPs for eggs is shown in Table 6.8. Finally, Hazard Analysis and Critical Control Point (HACCP) plan is given in Table 6.9. The comparison between CCPs of HACCP and ISO 22000 is summarised in Table 6.10.

6.2 CASE STUDY

6.2.1 Presentation of the egg production firm

The company has as its main activity, the production and marketing of chicken eggs. The enterprise is supplied from two chicken pens with a total holding capacity of 40,000 hens, with modern equipment.

The hens are held in multi-storey cages that allow a uniform distribution of air and light as well as the direct mechanic removal of pollutants and eggs, so as to maintain cleanliness and allow clean eggs to be collected. The company renews its flock at regular intervals, buying pullets of laying age from specific, approved suppliers.

The process of screening eggs is carried out in the candling centre. The candling centre of this unit is modern and it meets all the constructional requirements (industrial concrete, air-conditioned space, efficient cleaning, trained personnel) of good-quality systems. The eggs are collected daily and transported to the candling centre. There, they pass through the process of candling and weighing (using an automatic scale), after that they are separated qualitatively, are categorised by weight and are stamped with the code of the stock farm and packed in corresponding packing cases. Then they are kept chilled (max 5°C). Finally, the eggs are transported and distributed,

Table 6.6 Analysis of hazards in egg production.

Processing step	Hazard	Description of possible hazard
Breeding management of hens – egg management	Microbiological	Growth of the following micro-organisms: • *Salmonella* spp. • *Staphylococcus aureus* • Yeasts, moulds Contaminated feeds/water, disease of hens, poor hygienic conditions, rapid temperature changes affecting the eggs, careless management of eggs (cracked–broken eggs)
	Chemical	Antibiotics, insecticides
Transportation of eggs to the company	Microbiological	Growth of moulds in the case of wrong temperature Poor hygienic conditions in the transportation vehicles
Eggs receipt	Microbiological	Possible receipt of washed eggs with immediate result the destruction of the egg protection membrane and the growth of micro-organisms
	Physical	Receipt of eggs with foreign matter, e.g. broken eggshells or dirty eggs
Packaging materials receipt	Physical, microbiological	Presence of insects or dirt or parasites in the case of materials not packaged well or maintained in bad condition
Storage of eggs	Microbiological	Growth of moulds in the case of deviations of temperature and humidity
Candling	Microbiological	Presence of broken–cracked eggs whose eggshell could cause the growth of yeasts and moulds
		Presence of dirty eggs
	Physical	Presence of eggs with blood – foreign matter – eggs with genital cell
Packaging	Chemical	Migration of packaging materials into products
	Microbiological	Presence of broken–cracked eggs
		Contaminated packaging materials
	Physical	Wrong printing of the required data (lot number, expiry date, instructions of use and maintenance) in small packages or cartons with the result of loss of traceability or insufficient information for the consumers
		Presence of insects, dust in the packaging materials coming into contact with products
Final products	Physical	Absence of fresh eggs of the previous stages
		Contaminated foreign materials
	Microbiological	Presence of micro-organisms grown from previous stages but not detected: Mainly *Salmonella* spp. but also *Staphylococcus aureus*, yeasts and moulds
Storage of final products in the distribution centre or the warehouse	Microbiological	Growth of moulds in the case of non-conformance to the proper conditions of temperature–humidity or exceeding the permissible storage time
Distribution	Microbiological	Growth of moulds in the case of non-conformance to the proper temperature conditions
		Non-compliance with the required hygienic conditions in trucks
Cleaning–disinfection–pest control	Chemical	Use of non-approved cleaning and disinfection materials
Machinery lubrication	Chemical	Non-food grade lubricant materials
GMPs	Physical, microbiological	Lack of cleanliness of storage rooms, equipment, personnel
		Presence of insects/rodents
Storage – water use to clean	Chemical	Deviations in the chemical composition of water compared to specifications (excessive chlorination)
	Microbiological	Presence of coliforms in the water – wrong and irregular cleaning of water tank
Consumer use	Physical, microbiological	Non-compliance with maintenance conditions of products – consumption after the expiry date

Table 6.7 Determination of critical control points in egg production line.

A/A	Step	Hazard	Do control measure(s) exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of a hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable levels?	Will a subsequent step eliminate identified hazards or reduce likely occurrence to acceptable levels?	CCP
1	Receiving of raw materials	μ	Yes	Yes		No	CCP1
		C	Yes	No	No	No	cp
		P	Yes	No	No	No	cp
2	Receiving of spring chicken	M	Yes	Yes		No	CCP2
		C	Yes	No	No	No	cp
		P	Yes	No	No	No	cp
3	Receiving of additional materials	M	Yes	No	No	No	cp
		C	Yes	No	No	No	cp
		P	Yes	No	No	No	cp
4	Receiving of packing materials	M	Yes	No	No	No	cp
		C	Yes	No	No	No	cp
		P					
5	Storage of raw materials	M	Yes	No	No	No	cp
		C	Yes	No	No	No	cp
		P	Yes	No	No	No	cp
6	Storage of additional materials	M	Yes	No	No	No	cp
		C	Yes	No	No	No	cp
		P	Yes	No	No	No	cp
7	Storage of packaging materials	M	Yes	No	No	No	cp
		C	Yes	No	No	No	cp
		P					
8	Grinding of fruits	M	Yes	No	No	No	cp
		C	Yes	No	No	No	cp
		P	Yes	No	No	No	cp
9	Weighing	M	Yes	No	No	No	cp
		C	Yes	No	No	No	cp
		P	Yes	No	No	No	cp
10	Blending	M	Yes	No	No	No	cp
		C	Yes	No	No	No	cp
		P	Yes	No	No	No	cp
11	Pullet–hen layer paste	M	Yes	No	No	No	cp
		C	Yes	No	No	No	cp
		P	Yes	No	No	No	cp
12	Storage in silo	M	Yes	No	No	No	cp
		C	Yes	No	No	No	cp
		P	Yes	No	No	No	cp
13	Pullet–hen layer feeding	M	Yes	No	Yes	Yes	cp
		C	Yes	No	Yes	Yes	cp
		P					
14	Egg production	M	Yes	No	No	No	cp
		C	Yes	No	No	No	cp
		P	Yes	No	No	No	cp

(*Continues*)

Table 6.7 (Continued)

A/A	Step	Hazard	Do control measure(s) exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of a hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable levels?	Will a subsequent step eliminate identified hazards or reduce likely occurrence to acceptable levels?	CCP
15	Egg collection	M	Yes	No	No	No	cp
		C	Yes	No	No	No	cp
		P	Yes	No	No	No	cp
16	Transfer to the candling centre	M	Yes	No	Yes	Yes	cp
		C	Yes	No	No	No	cp
		P	Yes	No	No	No	cp
17	Candling	M	Yes	Yes		No	CCP3
		C	Yes	No	No	No	cp
		P	Yes	Yes		No	CCP3
18	Weighing	M	Yes	No	No	No	cp
		C	Yes	No	No	No	cp
		P	Yes	No	No	No	cp
19	Discission	M	Yes	No	No	No	cp
		C	Yes	No	No	No	cp
		P	Yes	No	No	No	cp
20	Codification	M					
		C	Yes	No	No	No	cp
		P					
21	Packing	M	Yes	No	No	No	cp
		C	Yes	No	No	No	cp
		P	Yes	No	No	No	cp
22	Cool storage	M	Yes	Yes		No	CCP4
		C	Yes	No	No	No	cp
		P				No	
23	Distribution	M	Yes	Yes		No	CCP5
		C				No	
		P	Yes	Yes		No	CCP5

in suitable egg vehicles, which belong to the company. Eggs must be consumed within 27 days of their production.

The whole eggs that are rejected at the candling centre are bought by industries specialising in the pasteurisation or separation and treatment of eggs, whilst the broken and perfect, but inadequate eggs are sent to be charred in a boiler. Final products are distributed using the factories' vehicles mainly to markets in the region of Epirus (NW Greece) but also in the neighbouring regions.

The birds are subjected to a strict immunisation programme and the veterinarian from the prefecture visits the installation regularly to collect samples for examination, from hens and eggs in order to check the sanitary conditions. The results of these analyses are retained in records for a period that exceeds the shelf life of the product.

Particular emphasis is given by the enterprise to the diet of the birds. The production manager uses only forage of plant origin. The storage of forage is in modern silos. The distribution of food

Table 6.8 ISO 22000 analysis worksheet for the determination of prerequisite programmes for eggs.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Receiving of raw materials	Yes	Yes	No	No	No
Receiving of spring chicken	Yes	Yes	No	No	No
Receiving of additional materials	Yes	Yes	No	Yes	Yes
Receiving of packing materials	Yes	Yes	No	Yes	Yes
Storage of raw materials	Yes	Yes	No	Yes	Yes
Storage of additional materials	Yes	Yes	No	Yes	Yes
Storage of packaging materials	Yes	Yes	No	Yes	Yes
Grinding of fruits	Yes	Yes	No	Yes	Yes
Weighing	Yes	Yes	No	Yes	Yes
Blending	Yes	Yes	No	Yes	Yes
Pullet–hen layer paste	Yes	Yes	No	Yes	Yes
Storage in silo	Yes	Yes	No	Yes	Yes
Pullet–hen layer feeding	Yes	Yes	No	Yes	Yes
Egg production	Yes	Yes	No	Yes	Yes
Egg collection	Yes	Yes	No	Yes	Yes
Transfer to the candling centre	Yes	Yes	No	Yes	Yes
Candling	Yes	Yes	No	No	No
Weighing	Yes	Yes	No	Yes	Yes
Discission	Yes	Yes	No	Yes	Yes
Codification	Yes	Yes	No	Yes	Yes
Packing	Yes	Yes	No	Yes	Yes
Cool storage	Yes	Yes	No	No	No
Distribution	Yes	Yes	No	No	No

throughout the aviary is automated. The unit is completely equipped and modernised. Successful application of HACCP principles by the company is required.

6.2.2 Organisation of enterprise – responsibility of administration

The administration of the enterprise recognises and accepts the responsibilities that are related to the quality and safety of the products. Specifically, these responsibilities are:

- Executive responsibility of determination and documentation of policy and engagement with regard to the recognition, evaluation and control of risks related to food safety.
- Responsibility for definition of field of application. The field of application determines the products/categories of products and the units of production that are covered by the system.

Table 6.9 Synoptical presentation of HACCP plan for egg production.

CCP	Step	Hazard	Control measures	Critical limits	Monitoring CCP				Corrective action	Records	Verification
					What	How	When	Who			
1	Receiving of raw materials	Microbiological and chemical contamination	Supplier certification	*Salmonella* absence in 16 g/sample Dioxines (PCDD and PCDF) 3 pg WHO-PCDD/F-TEO/g Remains of insecticides (legislation limits)	Supplier certificate	Produce certificate documents	Per receipt	Supply manager	Disposal–combustion	Supplier records	Laboratory tests
			Inspection of raw materials Adequate cleaning and pest control in storage place	Package and conveyances cleaning Absence of filth and pests	Receipt records	Visual control Cleaning and maintenance procedure	According to the cleaning and disinfection programme Pest control programme	Quality controller	Return the incoming materials	Cleaning records Pest control records	Internal review
			Humidity control			Humidity measurement	Each receival				
2	Receiving of spring chicken	Microbiological contamination	Chicken health certification	Transportation conditions	Health certificate	Produce certificate documents	Per receipt	Supply manager	Return	Supplier records	Percentage of ill and dead incoming spring chicken
			Chicken certified by the veterinary public service Immunisation programme	Marek inoculation	Inoculations	Depends on the inoculum	According to immunisation programme	Veterinary	Medical advice	Veterinary records Laboratory tests records	Laboratory tests

3	Candling	Microbiological and physical contamination	Air conditioner	Temperature in candling centre <20°C	Temperature control Personal health status	Temperature recording device	At the start and the end of the candling process	Quality controller Quality controller	Disposal of the daily production	Temperature records	Thermometer calibration
			Personal cleanliness, suitable protective clothing, head covering and footwear Training (including cleaning and maintenance equipment)	Lamp conduction in good condition Height of chamber Extra A ≤ 4 mm A category ≤ 6 mm B category ≤ 9 mm Absence of genital cell Visible egg yolk, no perimeter, not away from the centre of the egg in case of rotation, no foreign matter	Personnal cleanliness	Health booklet Eye exam	From the municipal health commission At the start of food-handling activities	Quality controller	Personnel exclusion (people who carry diseases or illness) Advice to personnel Remove and destroy the foods (if personnel suffer or carry a disease or illness)	Personnel records Training records Health records Maintenance records	Internal review
4	Cool storage	Microbiological contamination	Temperature control	Temperature 8–22°C, storage time 7 days, RH: 60–75%	Temperature	Temperature recording device	3 times/day	Production manager	Disposal–combustion	Temperature, calibrations	Thermometer calibration
			Adequate maintenance and cleaning Avoid pest access and harbourage	Filth and pest absence	Cleaning and disinfection	Cleaning and disinfection programmes–records	According to the cleaning and disinfection programme Pest control programme	Cleaning manager		Pest control records	Laboratory tests Internal review
5	Distribution	Microbiological and physical contamination	Temperature control	Temperature 20°C	Temperature	Temperature recording device	During the delivery	Distribution manager	Recall	Temperature, calibrations	Thermometer calibration
			Adequate maintenance and cleaning	Absence of dirt	Conveyances cleaning and disinfection	Cleaning and disinfection programmes–records	According to the cleaning and disinfection programme			Cleaning and disinfection records	Internal review

Table 6.10 CCPs of HACCP and ISO 22000 for eggs.

Process stage	CCPs of HACCP	Prerequisite programme?	CCPs of ISO 22000
Receiving of raw materials	1	No	1
Receiving of spring chicken	2	No	2
Receiving of additional materials		Yes	
Receiving of packing materials		Yes	
Storage of raw materials		Yes	
Storage of additional materials		Yes	
Storage of packaging materials		Yes	
Grinding of fruits		Yes	
Weighing		Yes	
Blending		Yes	
Pullet–hen layer paste		Yes	
Storage in silo		Yes	
Pullet–hen layer feeding		Yes	
Egg production		Yes	
Egg collection		Yes	
Transfer to the candling centre		Yes	
Candling	3	No	
Weighing		Yes	
Discission		Yes	
Codification		Yes	
Packing		Yes	
Cool storage	4	No	3
Distribution	5	No	

- Responsibility that the policy conforms to the objectives of enterprise and the requirements of customers for the production of safe foods, taking account of the sensitivity of users, legislation and being responsible for ensuring appropriate consideration of new scientific data relating to the risks from the foods.
- Guarantee that the food safety policy is comprehensible and is applied at all levels of the organisation.

6.2.3 The food safety policy of the egg manufacturing firm

The field of application of the system concerns the collection, candling, classification (per quality and weight), packing, storage and distribution of eggs that are produced in the enterprise's aviary.

The policy of the company with respect to food safety is that it should satisfy the daily running activities and needs of company, consumers and possible sensitive users. Permanent appropriateness is ensured by regular examination and harmonisation with the current legislation and with any new scientific data relating to the technology and the hygiene of foods. Moreover, the administration guarantees the commitment and disposal of essential resources necessary to the support of the HACCP system and for the application of most modern production technologies that correspond with the requirements of company and consumers.

6.2.4 Rules for good manufacturing and hygiene practice (GMP-GHP-SSOPs)

Sanitation standard operation procedures (SSOPs) were first implemented in the meat and poultry industries when they came under HACCP regulations. These procedures are currently implemented in the egg processing industry. It has been reported that bacterial counts for the surfaces of washed eggs correlate with counts for equipment surfaces and wash water (Moats, 1981). Furthermore, the major contamination source for wash water was found to be the eggs, not the equipment.

The primary sources of contamination in a processing facility have been determined to be direct and indirect contact surfaces, water, air and personnel (Slade, 2002). Drains, transportation equipment within the plant and maintenance equipment were also identified as possible sources of contamination during processing. An audit of a processing plant's sanitation programme can give a company a better understanding of the programme's effectiveness. There are publications that explain sanitation audits (Vasavada, 2001)

and rapid methods available for sanitation sampling (Russell, 2001). Furthermore, effective cleaning is not always achieved during sanitation. Many processing plant personnel do not read labels on disinfectants used at the facility (Powitz, 2002).

SSOPs are an integral component of process control and are often the first step in the implementation of food safety regulations. Jones *et al.* (2001) assessed and compared the efficacies of sanitation programmes used in a variety of shell egg processing facilities. In-line, off-line, and mixed operations were evaluated.

Sixteen direct or indirect egg contact surfaces were sampled in various shell egg processing facilities in the southeast USA. Samples were collected at the end of a processing day (POST) and again the next morning before operations began (PRE). Total aerobic plate counts (APCs) were obtained and *Enterobacteriaceae* were enumerated. No significant differences ($p > 0.05$) between POST and PRE bacterial counts were found for the 16 sampling sites. In general, high APCs were found on the wall of the recirculating water tank for both POST and PRE. The APCs for the rewash belt were considerably higher for all plants sampled. APCs were also high for the vacuum loaders. APCs for washers and washer brushes were relatively low for most plants sampled. PRE and POST levels of plant sanitation, as determined by direct microbial plating, did not differ significantly.

While it appears that more aggressive cleaning practices are warranted for the shell egg industry, it is also important to determine whether this industry should be held to the same sanitation standards as the meat and poultry industries. Although shell eggs are raw products, bacterial counts for the surfaces of washed eggs are much lower than those for raw poultry carcasses (Lucore *et al.*, 1997). The natural antimicrobial aspects of the egg also help to prevent the proliferation of micro-organisms.

6.2.4.1 *Lighting*

All the installation is equipped with suitable lighting. In the chicken pen, the artificial-regulated lighting is provided by glow lamps. In the candling and packing centre as well as in the cool storage, the lamps are protected with a plastic cover so that there is no danger of dissemination of glass in case of fracture.

6.2.4.2 *Ventilation*

The ventilation is sufficient and prevents undesirable accumulations of heat, steam and dust. In the candling centre, the ventilation in the forage deposit is achieved by means of fans while in the silos there is an automatic ventilation system using turbines.

In the aviary, all the booths are provided with an automatic ventilation system with filters that cause positive pressure. Also, in the case of extreme temperature and humidity the booths have an automatic system for complete environmental control.

6.2.4.3 *Waste disposal*

Waste products must be disposed of in a hygienic, environmentally responsible manner so that eggs and egg products for human consumption are protected from contamination.

Suitable installations for correct waste management exist. Specifically, at the aviaries the waste is collected automatically into trucks outside the booths and is transported away from the site. Solids are assembled at a separate location outside the installation, and are made into fertilisers for the fields.

The human sewage is collected in a cesspool that exists in the installation, whereas sewage from the candling centre is assembled in stainless siphons (absence of rodents) leading to a separate cesspool from that of human sewage. For the dead birds and the rotten eggs that cannot be sold to the pasteurisation industries the enterprise has manufactured a boiler system.

- All waste materials must be removed frequently from processing rooms and from the premises daily.
- Rejected eggs and egg products shall be disposed of on an appropriate tipping site by burial.
- Rejected eggs and egg products shall not be used as animal feed unless they are further heat-treated to eliminate pathogens.
- Sanitisers must be disposed of in accordance with Environmental Protection Agency guidelines.
- Dead birds shall be collected promptly and placed in waterproof, leakproof containers prior to incineration, burial or other approved outdoor method, away from the poultry shed.
- Litter and/or poultry manure can be removed off site, spread on surrounding land with an effective buffer distance to the poultry shed or stored on site in a dry weatherproof building at an effective buffer distance from poultry sheds. In the case of mobile shedding, a buffer distance is less relevant.

6.2.4.4 *Hygiene installations*

In the enterprise there are two separate locker spaces for personnel which are provided with closets. The one locker space meets the needs of personnel that work

in the aviary and the second, the personnel that work in the candling centre and in the packing area. There should be separate areas or rooms for the following processes:

- storage of eggs and unprocessed raw egg product
- breaking of eggs
- processing of eggs
- storage of processed egg product
- storage of additives
- storage of cleaning and sanitising products.

6.2.5 Egg production

Implementation of HACCP analysis was very effective, because it permitted the detection of potential and serious failures in production process. Estimation of these failures was carried out in the manufacturing process. Potential failures are described in the Table 6.11. Implementation of HACCP was carried out separately, per section involved. Current commercial practices decrease microbial contamination of eggshell surfaces. Larger operations that utilise high-speed washing and packing machines are common in today's shell egg industry (Zeidler, 2002).

Five different shell egg surface microbial populations (aerobic bacteria, yeasts and moulds, *Enterobacteriaceae*, *E. coli*, and *Salmonella*) were monitored by Musgrove *et al.* (2005) at 12 points along the processing line (accumulator, pre-wash rinse, washer 1, washer 2, sanitiser, dryer, oiler, scales, two packer head lanes, rewash entrance and rewash exit). Three commercial facilities were each visited three times, a total of 990 eggs were sampled, and 5220 microbiological samples were subsequently analysed. Although variations existed in concentrations of micro-organisms recovered from each plant, the patterns of fluctuation for each population were similar at each plant. On average, aerobes, yeasts and moulds, *Enterobacteriaceae*, and *E. coli* prevalence were reduced by 30, 20, 50, and 30%, respectively, by the end of processing. Commercial egg processing significantly reduced concentrations of aerobic bacteria, yeasts and moulds, *Enterobacteriaceae*, and *E. coli* in shell egg rinses. Populations decreased once eggs reach the first washer and remained at low levels through packaging. *Salmonella* was isolated at every sample collection site on at least one of the nine plant visits. Pre-process shell egg rinse or crushed eggshell and membrane samples were positive for *Salmonella* more often than in-process or post-process samples. Wash water pH, temperature and condition (e.g. potability or contamination with organic material) seemed to partially account for the ability of *Salmonella* to survive the commercial process. *S. enteritidis* was not recovered from any of the samples. Two flow diagrams of egg production are given in Figs. 6.1 and 6.2, respectively and the flow diagram of poultry farm-candling place is given in Fig. 6.3. The Ishikawa diagram of non-conformity egg is shown in Fig. 6.4.

6.2.5.1 Egg-laying room

The production failure mode and effect's analysis (PFMEA) team detected the potential failure modes for each part of the room equipment. The most important failures focus on cleaning, performance, equipment, with serious effects on final product or hen's health. Infection with micro-organisms is of high severity for the product as it is related to the safety of the final product and consequently with consumer's health. Poor implementation of GHPs (good hygiene practices) is closely related with insufficient cleaning of trays. Systematic cleaning and disinfection by educated staff should be employed as an action measure.

Cleaning of process plants is costly and time-consuming. It is important to understand the removal of fouling deposits. Deposits are formed by adhesion to the surfaces and cohesion between elements of the deposit. Cleaning can result from either or both adhesive and cohesive failure. Micromanipulation experiments have measured the adhesive/cohesive strength of deposits in terms of the work required to remove them from the surface. Different food deposits have been studied. Egg albumin deposits have a lower adhesive than cohesive strength (Liu *et al.*, 2006).

The causes of failures have been ranked by means of a Pareto diagram where corrective actions for the 20% of causes of failures with the highest RPN (risk priority number) were recommended. Later, further corrective actions were suggested for the remaining causes of failures.

Practices that are expected to be carried out by the hatchery, breeder or rearer are:

- Unique genetic material shall be kept in more than one building and preferably on more than one holding or site.
- Adequate distance shall be present between buildings used for pullet rearing and egg production.
- Adequate ventilation shall be provided at the breeder/hatchery premises.
- Only clean eggs which have been sanitised shall be selected for incubation.
- At hatcheries, eggs shall be collected from breeding farms regularly.
- In a hatchery, a one-way flow of eggs and chicks shall operate (Australian Egg Corporation Limited, 2005a).

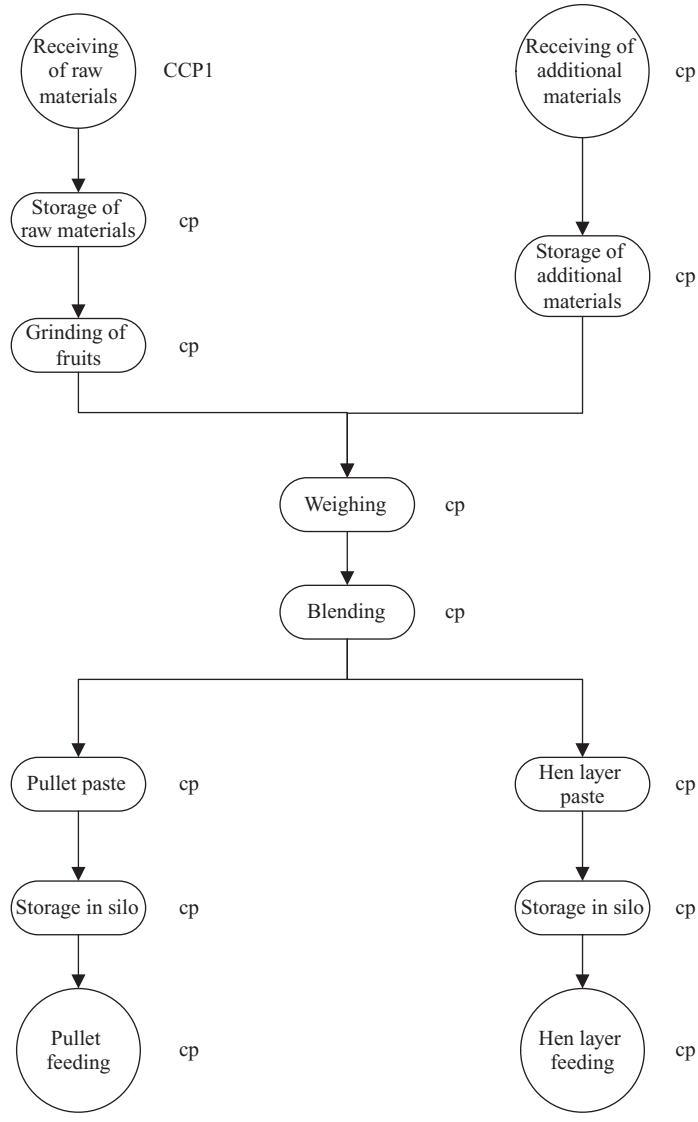

Fig. 6.1 Flow diagram of pullet and hen layer feeding.

Hens for laying shall be maintained in a healthy state to ensure a safe egg supply.

- Vaccination programmes shall be developed and implemented in consultation with the hatchery, which supplies birds. Any signs of unusual illness or poor health in a flock shall be immediately drawn to the attention of a veterinarian or the responsible department in the state or territory in which the farm is based.
- Sick or injured birds shall be culled promptly.
- Eggs for human consumption shall be taken only from healthy stock. When medication has been given to a flock, eggs shall not be sold during the recommended withholding period as stated on the label.

Dietary moult induction to initiate additional egg-laying cycles in commercial laying hen flocks is a wide spread practice all over the world. Feed deprivation is the most commonly used method but this practice has generated concerns which have led to research

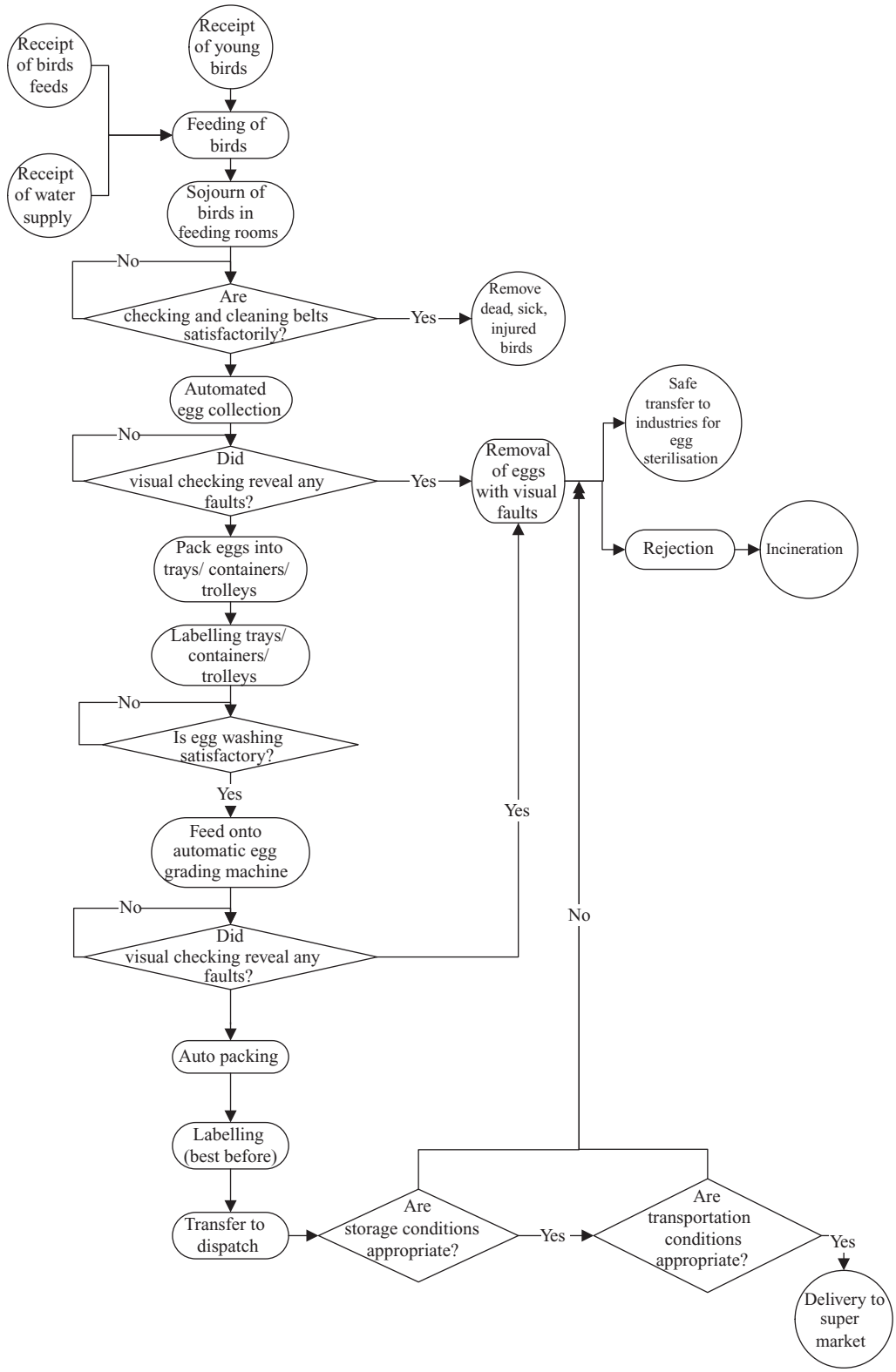

Fig. 6.2 Flow diagram of egg production.

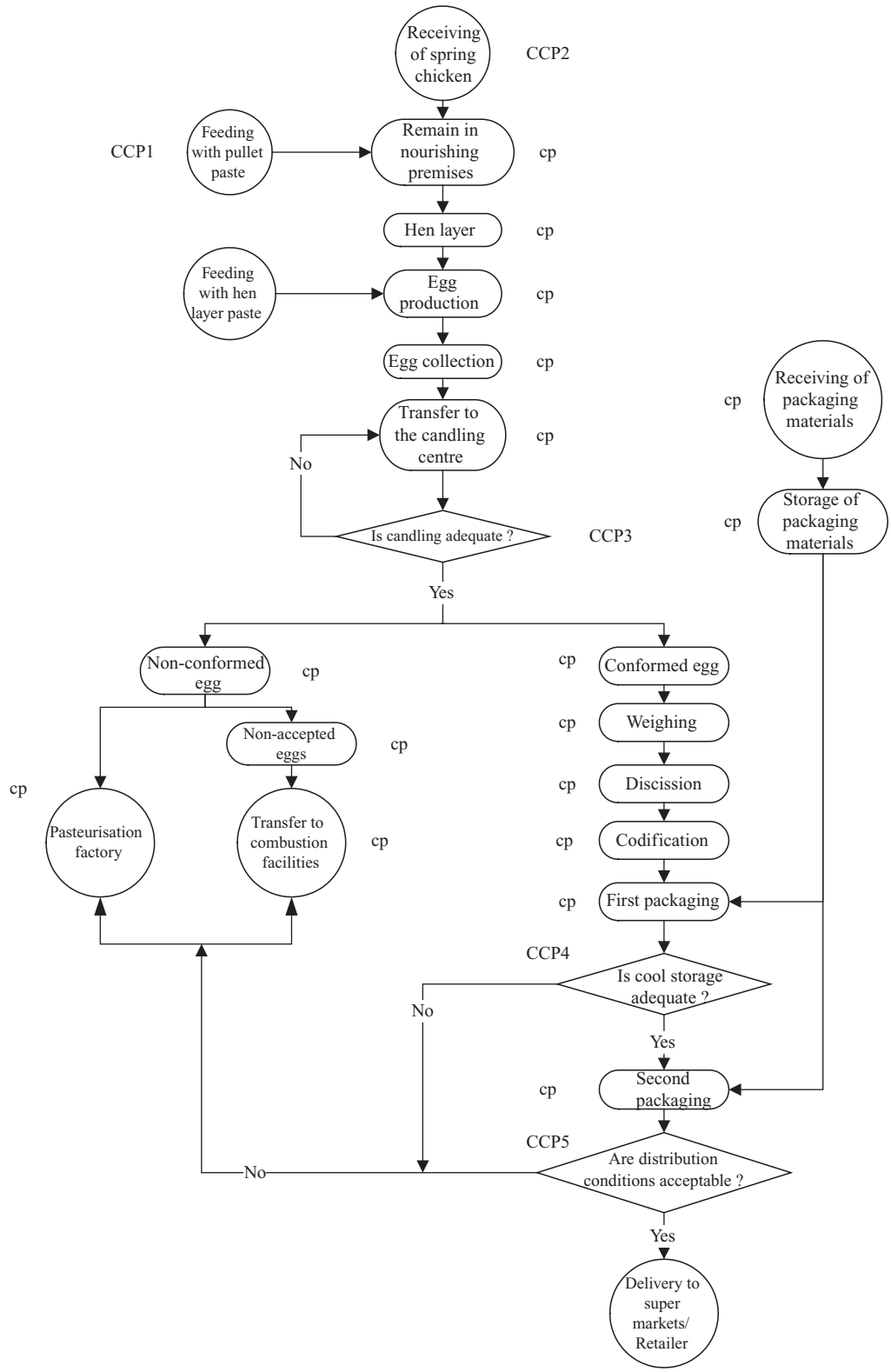

Fig. 6.3 Flow diagram of poultry farm-candling facility.

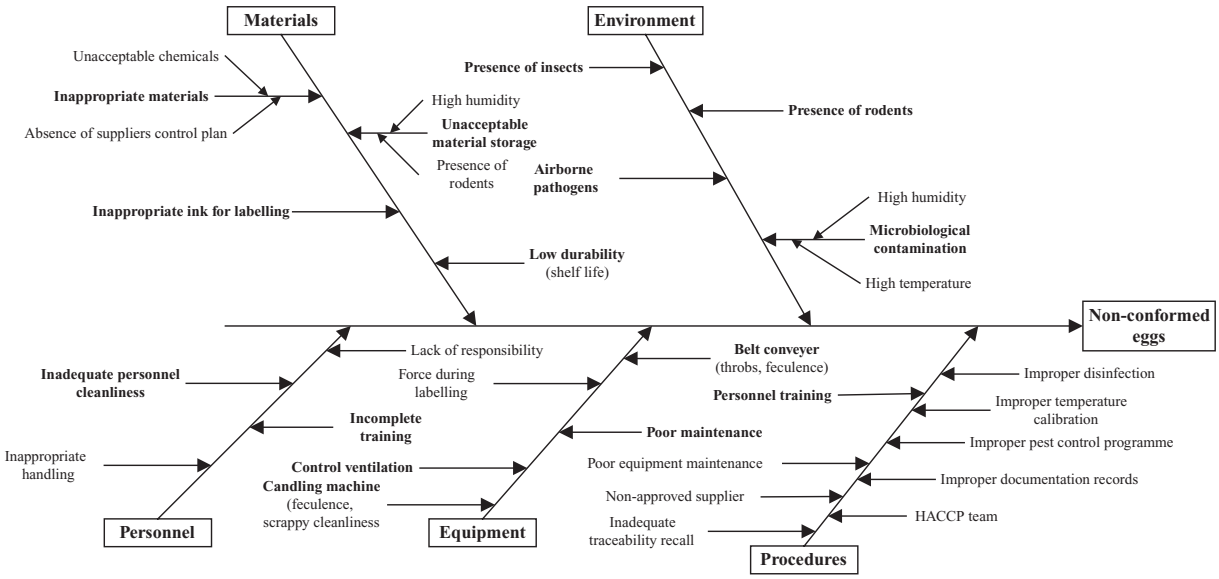

Fig. 6.4 The Ishikawa diagram for non-conformed eggs.

for viable alternative approaches. From a management standpoint, a single ingredient moulting diet consisting of high fibre–low energy represents an easily adaptable diet for large laying hen production units. Alfalfa meal is readily available in most commercial locations and possesses many of the desirable properties of an ideal laying hen moult diet. Landers *et al.* (2005) moulted hens at a commercial laying facility by both alfalfa and feed deprivation. After the hens had reentered post-moult commercial egg production, eggs were examined for egg quality performance. Eggshell strength, albumen height, yolk height, weight, length and yolk colour were all tested using various mechanical techniques. The eggs were also sampled for testing by consumer sensory panels that assessed the overall acceptance of the eggs' colour and flavour/texture. Eggs laid by hens moulted by alfalfa had a significantly lower ($p < 0.05$) α^* level of colorimetry. Eggs laid by hens moulted with alfalfa also exhibited significantly higher ($p < 0.05$) egg weights and length. In the consumer sensory test, there was no significant difference ($p > 0.05$) in colour or flavour/texture scores in eggs from either feed-deprived or alfalfa-moulted hens. The consumer's sensory and mechanical quality attributes indicate that alfalfa showed promise as an alternative moult induction diet by providing a single diet option for extending egg production into a second egg-laying cycle.

Breeder hens in the beginning of their productive life tend to lay eggs of a reduced size (less than 50 g). These fertile but small eggs are usually directed to industrialisation and commercialised as dried or liquid egg. When the demand for broiler chicks is great, however, it is common for small eggs to be incubated.

Characteristics related to hatchability, such as fertility, the time required to rupture the internal and external membranes, and hatching proper (neonate completely dry and membrane free), can be influenced by the age of the breeder hen. Incubation time can be shorter in eggs from young breeders (Suarez *et al.*, 1997).

An evaluation of indices related to hatchability is required when these eggs are to be used for the production of broiler chicks. Pedroso *et al.* (2005) evaluated fertility, the time spent by the embryo to rupture the internal and external membranes, the percentage of hatchability, and embryo mortality of eggs from birds in pullet-to-breeder transition phase, at 25 and 27 weeks of age, and from breeders during the initial stages of the production period, at 32 and 37 weeks of age.

Embryos from heavy eggs of breeder hens at 37 weeks of age took less time to complete the hatching process. Results indicated that the larger the egg, the heavier the chick and shell, and the lesser the shell percentage. As breeder age advanced, characteristics related to egg fertility and hatchability improved.

Chen *et al.* (2005) evaluated the influence of storage temperature, storage time and initial contamination on

the fate of salmonellae in egg albumen. Storage at 4 and 10°C inhibited the growth of salmonellae in the albumen of eggs initially inoculated at 10^2, 10^4 or 10^6 cells per egg. The pathogen flourished at 22°C, even in the albumen that had the lowest initial population of 10^2 cells per egg. In eggs with an initial *Salmonella* population of 10^6 cells that were stored at 22°C, the populations reached as high as 10^{10} cells per egg after 4 weeks of storage. The outgrowth of salmonellae at 22°C from an inoculum of 10^6 cells per egg was correlated with the poor qualities of albumen and vitelline membrane under these conditions.

When the eggs were stored at 4°C, the albumen retained significantly more volume and weight and had a relatively lower pH. The vitelline membranes from eggs stored at 4 and 10°C required more force and energy for rupture. Storage at 4 and perhaps 10°C postponed the ageing process of chicken eggs, preserved the antimicrobial agents of the albumen, and maintained the integrity of vitelline membrane. Low-temperature storage, therefore, had a significant impact on the safety and overall quality of the eggs.

The mechanics and mechanisms of failure of hens' eggs have been examined experimentally under contact loading conditions relevant to industrial conditions by testing eggs of known provenance in compression between stiff platens (Macleod *et al.*, 2006).

Deformation was modelled computationally as a Hertzian contact problem between a thin-walled elastic shell and a rigid plate. Contact damage was determined by scanning electron microscopy and by optical examination of transverse sections through the shell. Small stable micro-cracks were found to initiate in the contact area before structural failure, which was characterised by the propagation of one or more macroscopic cracks. Micro-cracks are formed by the high stress levels which develop on the inner surface of the eggshell. These subsequently propagate to the eggshell thickness as the shell conforms to the shape of the platen.

Micro-cracks are likely to form in eggs during routine egg handling as eggs collide with each other or part of the collecting machinery. Crack detection devices which rely on mechanical excitation cannot detect the presence of micro-cracks in eggs. As a result, micro-cracks could provide a direct route for potentially harmful bacteria to enter the egg contents, if the cuticle is incomplete or absent, allowing egg safety to be compromised. The process function, causes and effects of failure, and recommended actions taken in the egg-laying room are given in Table 6.11.

Visual checking centre

Eggs, through egg-carrying belts, are moved from the egg-laying room to the visual selection centre where control is operated for their prospective safety. The PFMEA team detects failures at this stage, so as to reduce or efface them. Failures focus on cleaning, performance and equipment preservation issues. Equipment cleaning is of great importance, as it is related to micro-organism's existence and egg infection. If the responsible staff keep to the regulations then problems are reduced.

It is important that each egg is visually checked so that the quality of eggs leaving the packing and candling process is assured. Equipment used in the grading process must be maintained in a clean condition to prevent the build-up of micro-organisms.

- Following washing, eggs shall be candled and visually checked to ensure good quality.
- Rejected eggs shall be placed into a container used solely for these eggs and labelled as such. The container shall be constructed so as to facilitate thorough cleaning and sanitisation after each use.
- Eggs shall be fed onto a manual or automatic egg grading machine, packed according to weight into specified units and labelled with a use by date and the name of the packer.

Visual appearance

Eggs shall be free from dirt or stains. Shells shall not be cracked, thin, rough or misshapen.

Internal characteristics

Yolk should be deep yellow-gold in colour. The internal colour will be measured with HunterLab chromatometer (L*, a*, b*). The latter is an apparatus measuring four parameters which are L* (lightness), a* (redness), b* (yellowness) and chroma parameter. Eggs shall be free from blood or meat spots. The process function, causes and effects of failure, and recommended actions taken in the visual selection centre are given in Table 6.12.

6.2.5.2 *Packing room*

Egg packing is one of the most crucial stages for their safety and hygiene. In this stage, failure with the higher RPN is related to the quality of packaging materials. Poor-quality packaging materials may harbour microbes with serious consequences for eggs' safety and hygiene.

The individual egg cartons must be stamped with a legible 'use by' or 'best before' date code. It is important to ensure that the ink used to stamp the eggs is made from a non-toxic material. A code identifying the packing station and farm must be marked on the egg. An alternative method may be used to enable the eggs to be traced back to the packing station and farm. All farms must ensure that they have an effective

Table 6.11 Process function, causes and effects of failure, and recommended actions taken in the egg-laying room.

Process function	Potential failure mode	Potential effects of failure	Potential causes of failure	Process control	Recommended actions	Responsible	Action taken
Many-storied trays (type: vertical four storeys, in order of three double lines)	Cleaning	Microbial hazard	Insufficient cleaning of cages (A)	Cleaning and disinfection	Cleaning and disinfection programme	Hygiene manager	Thorough cleaning and disinfection by trained staff
		Disinfectant–cleaning remnants	Inappropriate implementation of disinfectant–cleaning (B)	Implementation of disinfectant–cleaning	Proper implementation of disinfectants–cleanings in compliance with recorded instructions	Hygiene manager	Use of disinfectants and cleaning in compliance with recorded instructions of goods
			Use of prohibited disinfectant–cleaning goods (C)	Use of proper disinfectant–cleaning goods	Use of approved disinfectant–cleaning goods	Hygiene manager	Use of proper disinfectants and cleanings for bird rooms (record of approval license by drug organisation or general chemistry laboratory)
	Available space/hen	Reduction of egg production enhanced hens' death rate	Reduced available space per hen (D)	Observance of all the requirements about the available space per hen	Counting of sampled hens per cage at fixed time intervals	Hygiene manager	Sampling control for the discovery of hens' number per cage at fixed time intervals
Food automatic transport system (for feeding installations: linear which is filled automatically by a moving food carrying funnel)	Function (breaking of fuse at the lowest part of funnel)	Insufficient catering of hens – effects on egg production	Damage by insertion of hard particles inside the food (E)	Controls of cattle	Use of cattle feeds with high clearness and easy flow original materials	Production manager	Cattle feeds are used with high clearness and the original materials are of easy flow

	Cleaning	Effect on hens' hygiene	Presence of rodents, insects (F)	Implementation of disinfection Grilles on room windows Daily control of feeding installations	Disinfection programme	Production manager	Implementation of disinfection programme by certified company
		Effect on hens' hygiene by disinfectant–cleaning remnants	Poor application of disinfectant–cleaning (G)	Implementation of disinfectant–cleaning	Implementation programme of disinfectants–cleaning	Production manager	Proper implementation of disinfectants–cleaning according to GMP for the food industries
Automatic water transport system (waterer which functions according to the demand valve type)	Function (valve enclosure)	Failure of water supply	Impure water (containing particles and has high salt content) (H)	Use of tested water by drilling	Analyses of drilling water samples at intervals which are defined by a chemist	External accredited laboratory	Use of drilling water, following chemical laboratory approval Frequent inspections of watering equipment so that their normal faction is ensured
	Water quality	On hens' hygiene by chemical remnants	Infected water by toxic heavy metals (because of old pipes network (i.e. Cd) and pesticide remnants (I)	Use of tested water by drilling	Analyses of drilling water samples at intervals which are defined by a chemist	External accredited laboratory	Use of drilling water, following approval of the chemical laboratory Suitability controls of pipe nets
Lighting with windows with incandescence bulbs of 45 W (colour: yellow–orange)	Tension (of simple bulbs)	Drop of maximum egg production	Tension reduction below at level of feeding installation (J)	Use of bulbs in such a number and tension so that the criterion of lighting tension is at least 10 lux at level of poultry feeder Existence of generator and activation automatic system in case of current stoppage	Fixed sampling controls with the use of exposure meter	Production manager	Sampling controls at fixed time intervals, with the use of exposure meter

(*Continues*)

Table 6.11 (Continued)

Process function	Potential failure mode	Potential effects of failure	Potential causes of failure	Process control	Recommended actions	Responsible	Action taken
Automatic transport egg belts	Cleaning	Infected belts surface	Insufficient cleaning and disinfection (K)	Cleaning and disinfection	Thorough cleaning and disinfectant programme	Hygiene manager	Thorough cleaning and disinfection
		Chemical remains	Use of prohibited disinfectant–cleaning goods (L)	Use of proper disinfectant–cleaning goods	Use of approved disinfectant–cleaning goods	Hygiene manager	Use of proper disinfectants and cleaning for the aviaries
			Improper implementation (use) of disinfectants–cleaning (M)	Implementation of cleaning and disinfectants	Proper use of cleaning and disinfectants in compliance with the recorded instructions	Hygiene manager	Use of disinfectants and cleaning in compliance to the recorded instructions of goods
		Presence of insects, rodents	Presence of insects, rodents in the area (N)	Implementation of disinfection	Programme of disinfection by specialised staff	Hygiene manager	Disinfection by certified company of disinfections
		Presence of hair	No observance of hygiene regulations by the staff (O)	Proper clothing of staff	Staff training right hygiene regulations	Hygiene manager	Implementation of right hygiene regulations by the staff
	Maintenance	Presence of rust–grease	Improper maintenance of equipment (P)	Maintenance of equipment	Equipment maintenance programme by specialised staff and in compliance with instructions of the manufacturing company	Technical manager	Equipment maintenance in compliance with instructions of the manufacturing company Control of equipment maintenance file
	Function	Vibrations: egg cracks – entry of microbes	Poor belt function because of improper maintenance (Q)	Maintenance of equipment	Equipment preservation programme by specialised staff	Technical manager	Implementation of equipment maintenance programme in compliance instructions of the manufacturing company

							Control of equipment maintenance file
Airing system with filters (type: closed system tunnel helix)	Function	Effect on hens' hygiene: irritation of breathing organs, suffocation–death	Insufficient airing because of poor maintenance (R)	Maintenance of airing system	System maintenance programme by specialised staff	Technical manager	Implementation of airing system maintenance programme in compliance with instructions of the manufacturing company Control of system maintenance file
Automatic system of complete control of internal rates: temperature–humidity	Function	Temperature–humidity rates which negative impact on hens' hygiene – egg production – food exploitation – egg quality (terminal T i.e. T > 20–28°C effect unfavourably on shell gauge of eggs, because of excessive loss of CO_2 by hens, so that they cannot have enough carbonate salt any more)	Temperature and humidity rates except from permissible limits because of poor system maintenance (S)	System maintenance	System maintenance programme	Technical manager	Implementation of maintenance programme of airing system in compliance with instructions of the manufacturing company Control of system maintenance files
Cooling – humectation system (hydropanel placed on windows)	Function	Effect on hens' hygiene	Unsuitable temperature and relative humidity rates because of improper system maintenance (T)	Equipment maintenance	Equipment maintenance programme in compliance with instructions of the manufacturing company	Technical manager	Implementation of maintenance programme of airing system in compliance with instructions of the manufacturing company

Table 6.12 Process function, causes and effects of failure, and recommended actions taken for visual selection centre.

Process function	Potential failure mode	Potential effects of failure	Potential causes of failure	Process control	Recommended actions	Responsible	Action taken
Egg transport belts (automatic)	Cleaning	Infected belt surface	Insufficient cleaning and disinfection (A)	Cleaning and disinfection	Programme of thorough cleaning and disinfection	Hygiene manager	Thorough cleaning and disinfection
		Chemical remnants	Use of prohibited disinfectant–cleaning goods (B)	Use of proper disinfectant–cleaning goods	Use of approved disinfectant–cleaning goods	Hygiene manager	Use of proper disinfectants and cleaning for the aviaries (record of approval license)
			Improper implementation (use) of disinfectants–cleanings (C)	Implementation of cleaning and disinfectants	Proper use of cleaning and disinfectants in compliance with recorded instructions	Hygiene manager	Use of disinfectants and cleaning in compliance with recorded instructions
		Presence of insects, rodents etc.	Presence of insects, rodents in the area (D)	Implementation of disinfection	Programme of disinfections by specialised staff	Hygiene manager	Disinfection by certified company
		Presence of hair	No observance of hygiene regulations by the staff (E)	Property staff clothing	Staff training on right hygiene regulations	Hygiene manager	Implementation of right hygiene regulations by the staff
	Maintenance	Presence of rust–grease	Inadequate equipment maintenance (F)	Equipment maintenance	Equipment maintenance programme by specialised staff and in compliance with instructions of the manufacturing company	Technical manager	Equipment maintenance in compliance with instructions of the manufacturing company Control of equipment maintenance file
	Function	Vibrations: egg cracks – entry of microbes	Poor belt function because of improper maintenance (G)	Equipment maintenance	Equipment maintenance programme by specialised staff	Technical manager	Implementation of equipment maintenance programme in compliance with instructions of the manufacturing

							company Control of equipment maintenance file
Egg visual control (type of Holland (Stalkat) operates automatically)	Function	Changes are not detected inside the egg	Improper function because of improper maintenance (H)	Equipment maintenance	Maintenance programme of egg visual control by specialised staff	Technical manager	Implementation of egg visual control preservation programme in compliance with instructions of the manufacturing company Control of egg visual control maintenance file
			Negligence – incorrect staff handlings (I)	Specialised staff	Staff training in proper egg selection		Staff is properly trained for the process of visual check
	Cleaning	Mycotoxins	Improper implementation of disinfectants and cleaning (J)	Implementation of cleaning and disinfectants	Proper implementation of disinfectants and cleaning in compliance with recorded instructions	Accredited laboratory	Cleaning and disinfection programme in compliance with recorded instructions
Egg visual control (type of Holland (Stalkat) operates automatically)		Chemical remains	Unsuitable cleaning and disinfectants for the food industries (K)	Use of proper disinfectant–cleaning goods	Use of approved disinfectant–cleaning goods	Hygiene manager	Use of approved disinfectant–cleaning by drug organisation or state chemistry laboratory for the implementation in food industries
		Hair presence	No control of hygiene regulations by the staff (L)	Proper staff clothing	Staff training in right hygiene regulations	Hygiene manager	Implementation of right hygiene regulations by the staff

Table 6.12 (Continued)

Process function	Potential failure mode	Potential effects of failure	Potential causes of failure	Process control	Recommended actions	Responsible	Action taken
		Presence of insects	Presence of insects in the area (M)	Implementation disinfection	Programme of disinfections by specialised staff	Hygiene manager	Disinfection by certified company
	Maintenance	Rust–grease presence	Insufficient maintenance (N)	Equipment maintenance	Maintenance programme of egg visual control by specialised staff and in compliance with instructions of the manufacturing company	Technical manager	Maintenance of egg visual control in compliance with instructions of the manufacturing company Control of egg visual control maintenance file
Weighing machine	Function	Egg cracking – entry and growth of microbes inside the egg	Improper handling by the staff (O)	Specialised staff	Staff training	Technical manager	Staff properly trained for the process of egg weighing
			Increased pressure of machines (P)	Maintenance of weighing machine	Maintenance programme of weighing machine	Technical manager	Implementation of equipment maintenance programme in compliance with instructions of the manufacturing company Control of the weighing machine maintenance file
	Cleaning	Microbes' growth	Improper hygiene and disinfection conditions (Q)	Implementation of hygiene and disinfection regulations	Cleaning and disinfection programme of weighing machine	Hygiene manager	Implementation of the cleaning and disinfection programme of the weighing machine in compliance with food industries

Egg sealing machine (automatic machine domino A100)	Egg sampling ink	Chemical remnants inside the eggs	Use of unsuitable ink for the food (for egg stamping) (R)	Requirement for the covering certificate of suitability while buying ink	The purchase of the ink comes along with a certificate of suitability	Analytical manager	
	Function	Egg crack	Creation of greater pressure during the codification (S)	Equipment maintenance programme	Implementation of equipment maintenance programme in compliance with instructions of the manufacturing company	Technical manager	
					Control of equipment maintenance file		
	Cleaning	Chemical remains	Improper implementation of disinfectants and cleaning (T)	Proper implementation of disinfectants and cleaning according to the recorded instructions	Cleaning and disinfection programme in compliance with recorded instructions	Hygiene manager	
			Unsuitable cleaning and disinfectants for food industries (U)	Use of proper goods and cleaning	Use of approved cleaning and disinfectant goods	Hygiene manager	Use of approved disinfectants by EOF or GHK, for implementation in food industries
		Hair presence	No observance of hygiene regulations by the staff (V)	Proper staff clothing	Staff training in proper hygiene regulations	Hygiene manager	Implementation of correct hygiene regulations by the staff
		Presence of insects	Insect's presence in the area (W)	Application of disinfectants	Disinfection programme by specialised staff	Certified pest control manager	Disinfection by certified company

Table 6.12 (Continued)

Process function	Potential failure mode	Potential effects of failure	Potential causes of failure	Process control	Recommended actions	Responsible	Action taken
	Maintenance	Presence of rust/grease	Poor maintenance of the machine (X)	Equipment maintenance	Maintenance programme of stamping machine by specialised staff in compliance with instructions of the manufacturing company	Hygiene manager	Maintenance of stamping machine in compliance with instructions of the manufacturing company Control of equipment in compliance with file
Refrigerator	Function	Growth of microbes	Insufficient freezing (Y)	Monitoring of temperatures	Compliance with programme of temperatures	Hygiene manager	Implementation of observation programme of temperatures and timely intervention
			Freezing loss: improper maintenance bad insulation current stoppage door opening (Z)	No freezing loss: equipment maintenance proper insulation generator existence references to staff	No freezing loss maintenance programme insulation in compliance with norm standards	Technical manager	No freezing loss: implementation of maintenance programme insulation in compliance with norm standards
					Staff training		Properly trained staff
	Cleaning	Chemical remains	Improper implementation of cleaning and disinfectants (A1)	Implementation of cleaning and disinfectants	Proper implementation of cleaning and disinfectants in compliance with recorded instructions	Hygiene manager	Cleaning and disinfection programme in compliance with recorded instruction of goods
			Unsuitable cleaning and disinfectants for the food industries (B1)	Use of proper goods and cleaning	Use of approved disinfectant and cleaning goods	Hygiene manager	Use of approved disinfectants and cleanings goods by relevant authorities for implementation in food industries

		Presence of insects	Presence of insects (C1)	Implementation of disinfectants	Disinfection programme by specialised staff	External certified company	Implementation of disinfection programme by certified company Installation of air curtains on the fridge entry
		Presence of hair	Bareheaded staff (D1)	Staff properly trained	Staff training	Hygiene manager	Properly trained staff so that it observes firmly all the instructions
			Improper hygiene conditions (E1)	Cleaning and disinfection	Cleaning and disinfection programme	Hygiene manager	Implementation of disinfection and cleaning programme in compliance with what exists in food industries
Air-conditioning machine (simple type)	Function	Growth of microbes (*Salmonella* spp., fungus)	Unsuitable rates of temperature and humidity in visual check centre because of poor maintenance of air-conditioning machine (F1)	Equipment maintenance	Maintenance only by specialised staff and in compliance with instructions of the manufacturing company (about time, spare parts etc.)	Technical manager	Maintenance of air-conditioning machine in compliance with instructions of the manufacturing company Control of air-conditioning machine maintenance file

tracking procedure for their eggs that can be triggered in the event of a recall. All outer cartons shall be labelled with a production code ('packing date' or 'use by' date), weight details, number of eggs and name and address of packer. The process function, causes and effects of failure, and recommended actions taken in the packaging room are given in Table 6.13.

6.2.5.3 Staff

Staff mentality and behaviour are very important for the proper functioning of the aviary. Failures detected by application of PFMEA were mostly about keeping to hygiene regulations, because their imperfect storage increases the danger of microbiological contamination. If the industry trains properly its staff in the implementation of the regulations of GHP, failure will be prevented or limited. The recommended actions follow the causes of failures in the Pareto diagram. The process function, causes and effects of failure, and recommended actions taken by the staff are given in Table 6.14.

6.2.5.4 Young birds' growth room

The young birds' growth room is not involved in the production of the final product. It is the place where young birds are grown until they reach reproductive age. This stage is very important for the proper growth and good health of the chicks, so as to give quality eggs in future. To achieve all this, the room must fulfil the required presuppositions. Failures in the room focus on cleaning and on equipment or parts of it and on performance issues. According to the Pareto diagram, failure with the highest RPN (= 252) is related to the insufficient cleaning of trays. After the implementation of recommended action which consists of systematic cleaning and disinfection by trained staff, the RPN rate was reduced to 120. The process function, causes and effects of failure, and recommended actions taken in the young birds' growth room are given in Table 6.15. A representative flow diagram of the egg production process in an egg farm is given in Fig. 6. and the flow diagram of pasteurised egg product is given in Fig. 6.6. Comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with PRP for pasteurised egg product is summarised in Table 6.16.

6.2.6 Storage and transport of eggs and raw pulp to processing plants

6.2.6.1 Plant

Shell eggs and egg pulp must be transported to the processing plant in such a way that prevents contamination and growth of any micro-organisms that may be present in the eggs.

6.2.6.2 Shell eggs

- Eggs shall be transported to the egg processing plant in a vehicle that holds the eggs at a temperature not exceeding 20°C and within a system that avoids temperature fluctuations.
- On receipt at the premises, the eggs shall be placed in a cool room operating at below 20°C.
- Eggs held below 20°C throughout the production/distribution chain shall be processed within 7 working days from date of lay.
- Eggs that have been held at 8°C or below throughout the production/distribution chain shall be processed within a maximum of 8 weeks from date of lay.
- Shell-damaged eggs shall be kept below 8°C and be broken out within 4 days from date of lay.

6.2.6.3 Raw egg pulp

- Chilled liquid egg product brought in from another site shall be transported in a vehicle that can hold the pulp at a temperature lower than 5°C and then stored at the processing plant at a temperature of less than 5°C. The pulp shall be heat-treated within 48 hours of breaking the eggs.
- Frozen liquid egg brought in from another site shall be transported in a vehicle that can hold the frozen pulp at a temperature of –18°C or below and then stored at –18°C or below at the processing plant (Australian Egg Corporation Limited, 2005b).

6.2.7 Inspection of eggs

Eggs shall be candled prior to processing to remove rejected eggs. Eggs which have not been candled can be used, providing rejected eggs can be effectively sorted and removed on the egg breaking equipment:

- Eggs with the shell membrane broken and leaking heavily shall be discarded and not used in any egg product.
- Cracked eggs with the shell and/or membrane ruptured but not leaking can be added to pulp that is to be pasteurised, but must not be used for non-pasteurised egg pulp. Eggs pulled from a carcass, or rejected eggs shall not be used.
- Incubated clear eggs shall not be used for human consumption. These eggs are likely to contain high numbers of bacteria.

Table 6.13 Process function, causes and effects of failure, and recommended actions taken for packaging room.

Process function	Potential failure mode	Potential effects of failure	Potential causes of failure	Process control	Recommended actions	Responsible	Action taken
Packing	Packing materials	Growth of microbes	Improper quality of materials (A)	Assessment of suppliers. Visual control in the receipt	Certified suppliers	Production manager	The supplying of packing materials is carried out by certified suppliers
			Improper conditions of materials storing (B)	Proper storage conditions	Controls of storage conditions	Storage manager	The storing conditions are checked and there is direct intervention
			Materials' expacking and their exposition in infections (C)	De-packing of materials in proper time and place	Staff training programme	Packaging manager	Trained staff for the handling of packing materials
		Chemical remnants	Unsuitable packing materials for food (D)	Proper materials for food packing	Certificates of suitability for food packing	Packaging manager	There are certificates of suitability of packing materials
		Presence of insects	Presence of insects and/or animals in the storing area (E)	Implementation of rat killings and disinfection: insects' traps in area, grilles on windows	Rat killing and disinfection programme	Certified pest control company	Implementation of rat killing and disinfection programme by certified company
		Presence of hair	Bareheaded staff, poor hygiene conditions in the store (F)	Properly specified staff	Staff training programme	Production manager	Trained staff with proper clothing and applying good hygiene practice regulation issues
		Presence of dust, soil	Expacked and exposed materials in unclean area (G)	De-packing in right time and place	Staff training programme	Hygiene manager	Trained staff for the handling of packing materials

Table 6.14 Process function, causes and effects of failure, and recommended actions taken for staff.

Process function	Potential failure mode	Potential effects of failure	Potential causes of failure	Process control	Recommended actions	Responsible	Action taken
Staff of the aviary	Health	Infection with microbes (superinfection by the staff)	Carrier of microbes (A)	Engagement of healthy staff	Staff training on diseases' issues and infection	Personnel manager	Staff properly trained on disease issues Employer's information about the disease Disease license
	Training per responsibility area	Unsuccessful task performance	Bad or insufficient training (B)	Engagement of properly trained staff	Training course programme is obligatory	Personnel manager	Obligatory watching of training course programme by the staff for further learning improvement
	Clothing	Hair reject	Unsuitable clothing (absence of bonnets) (C)	Proper staff clothing	Staff training programmes	Personnel manager	Properly trained staff so it implements all the instructions about the clothing
	Observance of hygiene regulations of the company	Disinfection of micro-organisms	Non-compliance with hygiene regulations (D)	Existence of substructure on hygiene issues Observance of regulations by the staff	Training staff programmes in good hygiene practice regulations	Personnel manager	Staff properly trained so that it observes firmly all the regulations of right hygiene practice

Table 6.15 Process function, causes and effects of failure, and recommended actions taken in young birds' growth room.

Young-bird development room							
Process function	**Potential failure mode**	**Potential effects of failure**	**Potential causes of failure**	**Process control**	**Recommended actions**	**Responsible**	**Action taken**
Many-storied trays (type: vertical, four stores in order of three double lines)	Cleaning	Hazard by microbes	Insufficient cleaning of cages (A)	Cleaning and disinfectant	Cleaning and disinfection programme	Hygiene manager	Systematic cleaning and disinfection by trained staff
		Disinfectant–cleaning remnants	Improper implementation of disinfectant–cleaning (B)	Implementation of disinfectant–cleaning	Proper implementation of disinfectant–cleaning in compliance with recorded instructions	Hygiene manager	Use of disinfectants and cleaning in compliance with recorded instructions of goods
			Use of prohibited disinfectant–cleaning goods (C)	Use of proper disinfectant–cleaning goods	Use of approved disinfectant–cleaning goods	Hygiene manager	Use of proper cleaning and disinfectant for bird rooms (record of approval license)
	Available space/hen	Increase of hen death rate	Reduced available space per hen (D)	Observance of all the requirements about the available space for hens	Sampling counting of hens per cage at fixed time intervals	Storage manager	Sampling control for the discovery of the number of hen per cage at fixed time intervals
Automatic food transport system: (type of poultry feeder linear which is filled automatically by a moving food carrying funnel)	Function (breaking of fuse at the lowest part of funnel)	Insufficient catering of pullets effects on growth	Damage by incorporation of hard particles inside the food (E)	Controls during the preparation of cattle feeds	Use of cattle feeds with easy flow original materials	Technical manager	Cattle feeds are used with high clearness and the original materials are of easy flow

(*Continues*)

Table 6.15 (Continued)

Young-bird development room							
Process function	**Potential failure mode**	**Potential effects of failure**	**Potential causes of failure**	**Process control**	**Recommended actions**	**Responsible**	**Action taken**
	Function	Effects on hygiene of pullets	Presence of rodents, insects in poultry feeders (F)	Implementation of pest control Screens on windows Daily control of poultry feeders	Pest control programme	Hygiene manager	Implementation of pest control programme by certified company
		Effects on hygiene by disinfectant–cleaning remnants	Improper implementation of disinfectants–cleaning (G)	Implementation of disinfectants–cleaning	Implementation programme of disinfectants–cleaning	Hygiene manager	Proper implementation of disinfectants–cleaning in compliance with the food industries
Automatic water transport system functioning according to the demand (type: valve)	Function (valve enclosure)	Failure of water supply	Unclean water (it carries particles and has high salt content) (H)	Use of controlled water by drilling	Analysis of drilling water samples at intervals defined by a chemist	Hygiene manager	Use of drilling water, after the approval of the chemical laboratory Frequent inspections of drinking water placements so that their normal function is ensured
	Water quality	On hygiene of hens by chemical remnants	Infected water by toxic heavy metals (because of old pipes' network, e.g. Cd and pesticide remnants (I)	Use of controlled water by drilling	Analysis of water samples from drill at intervals defined by a chemist	Analytical laboratory manager	Use of drilling water, after the approval of the chemical laboratory control of pipes' network

Table 6.15 (Continued)

Young-bird growth room							
Process function	**Potential failure mode**	**Potential effects of failure**	**Potential causes of failure**	**Process control**	**Recommended actions**	**Responsible**	**Action taken**
Airing system with filters (type: closed system tunnel helix)	Function	Effects on pullets' hygiene • Irritation of breathing organs • Suffocation–death	Insufficient airing because of improper maintenance (J)	Airing system maintenance	System maintenance programme by specialised staff	Technical manager	Implementation of airing system maintenance programme in compliance with instructions of manufacturing company Control of system maintenance file
Automatic system of complete control of the internal rates: • Temperature • Humidity	Function	Temperature and humidity rates which impact negatively on: hygiene pullets, food exploitation	Temperature and humidity rates apart from the permissible limits because of poor system maintenance (K)	System maintenance	System maintenance programme	Hygiene manager	Implementation of maintenance programme of the airing system in compliance with instructions of the manufacturing company Control of system maintenance files
Cooling – humectation system (hydropanel placed on the windows)	Function	Negative effects on hygiene of pullets	Unsuitable rates of temperature and relative humidity because of bad system maintenance (L)	Equipment maintenance	Equipment maintenance programme in compliance with instructions of the manufacturing company	Technical manager	Implementation of maintenance programme of airing system in compliance with instructions of the manufacturing company

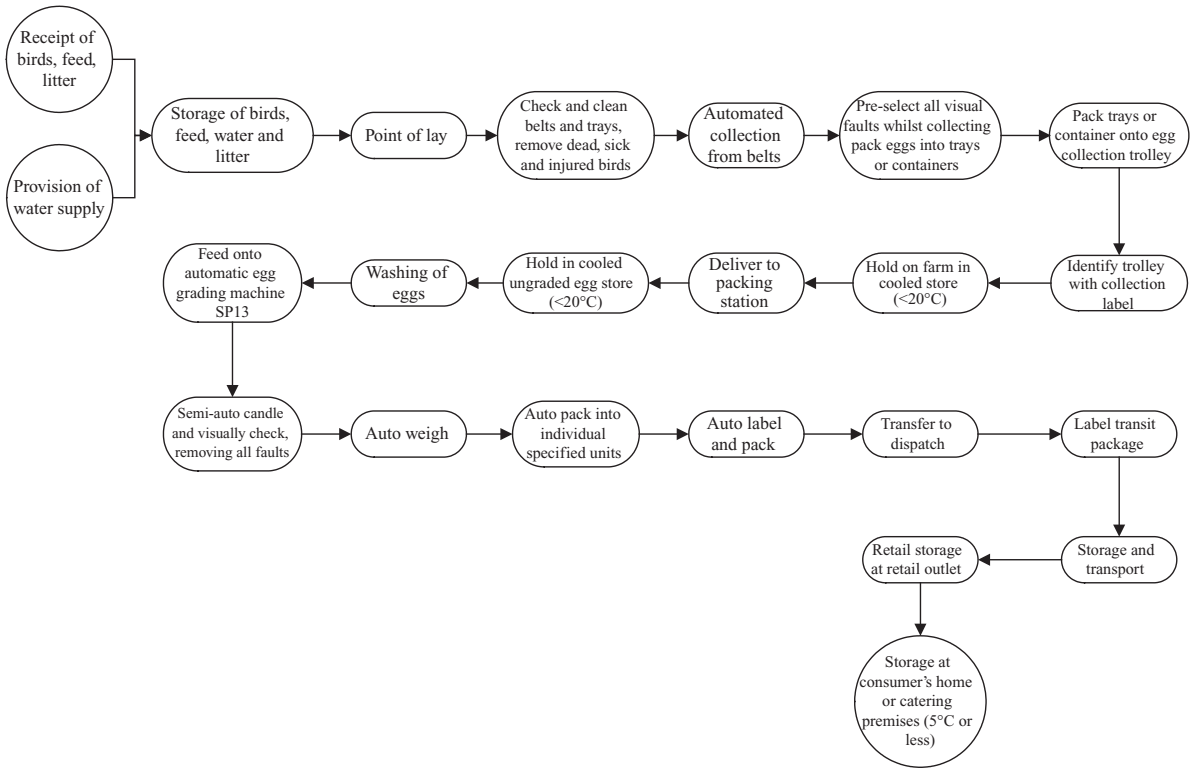

Fig. 6.5 Representative flow diagram of egg production process in an egg farm.

6.2.8 Cleaning/washing of eggs

Dirty eggs need to be cleaned before being broken. This must be carried out in an area that is separate from the breaking room where exposed egg contents are being handled. Washing removes the bloom from the eggshell making it easier for bacteria to get inside the egg through the pores. The risk of bacteria getting into unwashed dry-cleaned eggs is significantly reduced. If eggs are not washed, dirty eggs can be cleaned using a dry abrasive method. A clean, dry, sanitised cloth or other suitable material can also be used. The equipment used to clean eggs that are not washed must be sanitised or disposed of on a daily basis. Water used for washing eggs shall be free from pathogenic microorganisms or toxic chemicals.

The washing process shall be mechanised and continuous. Eggs shall not be allowed to stand or soak in the wash water (Australian Egg Corporation Limited, 2005b). To evaluate the effect of processing on the safety and quality of retail shell eggs, a storage study was conducted by Musgrove *et al.* (2004) with unwashed and commercially washed eggs. This work demonstrated that commercial processing decreased microbial contamination of eggshells. To know which species persisted during storage on washed or unwashed eggs, *Enterobacteriaceae* isolates were selected and identified biochemically. Shell eggs were purchased from a commercial processing plant, transported back to the laboratory and stored at 4°C. Once a week for six weeks, 12 eggs for each treatment (washed and unwashed control) were rinsed in sterile phosphate-buffered saline. A 1-mL aliquot of each sample was plated onto violet red bile glucose agar with overlay and incubated at 37°C for 24 hours. Following incubation, plates were observed for colonies characteristic of the family *Enterobacteriaceae*. A maximum of ten isolates per positive sample was streaked for isolation before being identified to the genus or species level using commercially available biochemical strips. Although most of the isolates from the unwashed control eggs belonged to the genera *Escherichia* or *Enterobacter*, many other genera and species were identified. These included *Citrobacter*, *Klebsiella*, *Kluyvera*, *Pantoea*, *Providencia*, *Rahnella*, *Salmonella*, *Serratia* and *Yersinia*. Non-*Enterobacteriaceae* also recovered from

the unwashed egg samples included *Xanthomonas* and *Flavimonas*.

Very few washed egg samples are contaminated with any of these bacteria. These data provide useful information on the effectiveness of processing in removing micro-organisms from commercial shell eggs.

Srikaeo and Hourigan (2002) illustrated the application of validation principles to evaluate the scientific and technical content of the CCP in a HACCP system. A commercial shell egg washing step was selected as a demonstration process. Validation procedures involved testing whether data obtained from the commercially operated plant agreed with the data reported in related literature and applying the appropriate statistical process control tools.

The results showed that the critical limits of all control measures defined for this CCP in the observed plant, pH of wash water (11–13), temperature of wash water (32–44°C), temperature of rinse water (41–49°C) and chlorine level (100–200 ppm) are in accordance with those generally recommended by many related references to ensure safe food production. Recommendations suggested by related literature were that pH of wash water should be 10–11, however, > 11 was tolerable, temperature of wash water should be at least 12°C higher than that of the eggs and not in excess of 50°C, temperature of rinse water should be slightly higher (3–4°C) than wash water temperature and the chlorine (sanitiser) level should be between 100 and 200 ppm. Hence, this CCP was judged to be valid.

The evaluation by applying the trial control charts to all collected data over the period showed that the process was not in control in all control measures (presence of tests of assignable causes). The process variability (control limit) was assumed as a 'current actual performance' and compared with the recommendations. Most control measures are satisfactory in terms of safe food productions. Some special considerations were made on particular control measures such as wash water temperature and chlorine level. The process capability studies were conducted for treated data and the results showed that all control measures are capable of the designed critical limits except the chlorine level whose process variation falls outside the width of critical limits.

Other recommended control factors of shell egg washing include the stricture that only fresh, intact eggs, that ideally have been stored at 10–14°C, should be washed. Commonly used sanitisers include 100–200 ppm of free available chlorine, quaternary ammonium compounds or calcium/sodium hypochlorite or 10–25 ppm iodine solution. Chlorination is the most

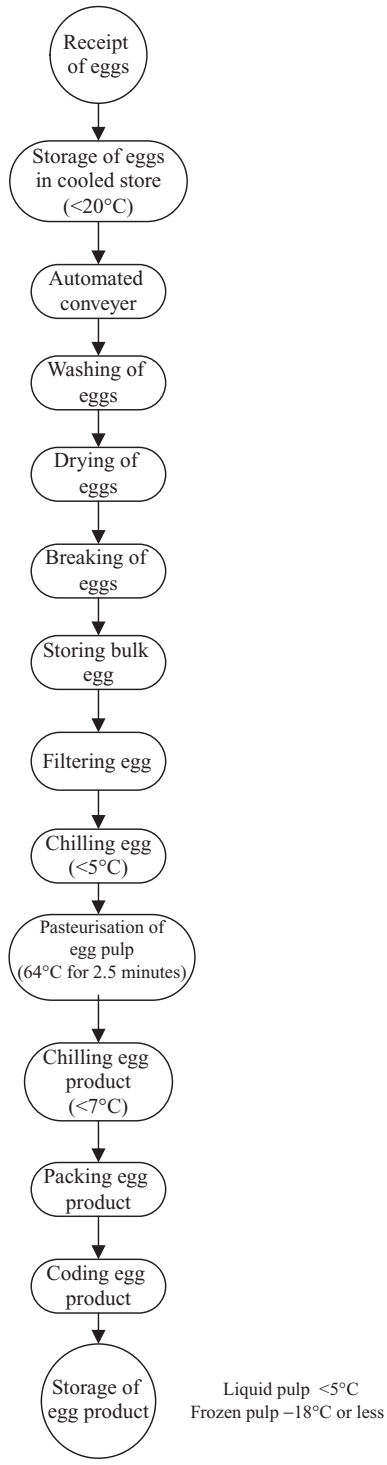

Fig. 6.6 Flow diagram for pasteurised egg product.

Table 6.16 Comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with prerequisite programme (PRP) for pasteurised egg product.

	HACCP				PRP				
Process stage	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**CCPs**
Receipt of eggs			CCP1				PRP		—
	Yes	Yes	—	—	Yes	Yes	No	Yes	
Storage of eggs in cold store	Yes	No	Yes	No			PRP		—
					Yes	Yes	No	Yes	
Automated conveyer	Yes	No	Yes	No			PRP		—
					Yes	Yes	No	Yes	
Washing	Yes	No	Yes	No			PRP		—
					Yes	Yes	No	Yes	
Drying	Yes	No	Yes	No			No PRP		—
					Yes	Yes	No	No	
Breaking of eggs			CCP2				No PRP		CCP1
	Yes	Yes	—	—	Yes	Yes	No	No	
Storing bulk egg	Yes	No	Yes	Yes			No PRP		—
					Yes	Yes	No	No	
Filtering			CCP3				No PRP		CCP2
	Yes	Yes	—	—	Yes	Yes	No	No	
Chilling			CCP4				PRP		—
	Yes	Yes	—	—	Yes	Yes	No	Yes	
Pasteurisation of egg pulp			CCP5				No PRP		CCP3
	Yes	Yes	—	—	Yes	Yes	No	No	
Chilling egg product			CCP6				PRP		—
	Yes	No	Yes	No	Yes	Yes	No	Yes	
Packing egg product	Yes	No	No	—			No PRP		—
					Yes	Yes	No	No	
Coding egg product	Yes	No	No	—			PRP		—
					Yes	Yes	No	Yes	
Storage of egg product			CCP7				PRP		—
	Yes	No	Yes	No	Yes	Yes	No	Yes	

widely used practice in the commercial egg washing and grading stations.

Some studies compared the efficacy of commonly used sanitisers (e.g. chlorine and others such as iodine-based and peroxidase-catalysed compounds) and suggested that these could be used as alternatives to chlorine (Knape *et al*., 1999; McKee *et al*., 1998). The purpose is to avoid the use of a single sanitiser (chlorine) and consequent problems of increasing bacterial resistance and toxic chlororganic compounds.

6.2.9 Egg pulping

The specialised equipment passes eggs through a candling inspection and washer (if required) before breaking them and pumping the pulp through filters or clarifiers. Eggs must be dry when opened to prevent bacterial contamination of the liquid egg from water droplets on the shell. The use of a centrifuge or any process involving crushing the whole egg to obtain egg pulp or white from empty shells shall only be done for the product which will be pasteurised as bacteria on the outside of the shell, including *Salmonella*, can get into the pulp during these processes. Centrifuges should only be used for the production of pasteurised frozen whole egg and whole egg powder where microbiological results can be obtained prior to dispatch and sale.

If a frozen pulp comes from another plant then the frozen raw egg pulp should be thawed prior to pasteurisation through a block chipper and into a steam-/water-jacketed stainless steel vat, which does not operate at higher than 60°C. The thawing process should be

completed within 2 hours and egg pasteurised within a further 2 hours.

6.2.10 Storage of egg pulp before processing

The product should undergo heat treatment as soon as possible after breaking the eggs. If treatment is not carried out immediately, liquid egg product must be stored under hygienic conditions at a temperature of less than 5°C for no longer than 24 hours after breaking the eggs.

- Egg products that are to be desugared, and then spray dried, may be held for 24 hours at less than 5°C prior to pasteurisation.

6.2.10.1 Pasteurisation

The objective in pasteurising raw egg is to kill pathogenic organisms, especially salmonellae, without affecting the physical and functional properties of the raw egg. The correct time and temperature must be used to ensure that the product is pasteurised. Once a product has been pasteurised, it is important to protect it from any risk of contamination.

(a) Liquid egg products
The equipment shall have:
- Attachments as may be necessary to ensure a constant flow rate of egg pulp
- Thermostatic control of the heating of the egg pulp
- The automatic diversion of flow of any whole egg not heated adequately
- Thermographs to record temperatures over time.

(b) Dried egg products
- Dried egg products shall be pasteurised prior to drying
- To kill all pathogens, dried egg white products processed from unpasteurised LEW shall be subjected to a suitable heat treatment process (such as hot room process), preferably in its final packaging. The product shall be held for at least 15 days in a room at a temperature of at least 60°C.

Because of the thermal fragility of LEW, spray-dried egg white (powder) is used by many sectors of the food industry. Since traditional pasteurisation of LEW (heating at 57°C for 2–6 minutes in EU) does not always destroy all pathogens, such as *Salmonella*, dry heating of the dried product (storage in a hot room under controlled temperature and moisture content) is advantageous for microbiological reasons.

In France, the traditional dry-heating treatment for dried egg white used in meat products is stored for about 15 days at 67°C. However, higher temperatures (up to 80°C) are also used to improve the functional properties (whipping and gelling) of the dried egg whites used in cakes, meringues, surimi and so forth.

Baron *et al*. (2003) investigated the effects of two dry-heating treatments (storage at 67 and 75°C for 15 days) on the subsequent ability of egg white to resist *Salmonella* growth after reconstitution. The impact on the endogenous microflora of the powder and on its functional properties was also considered. Both dry-heating treatments were efficient in destroying a large number of *Salmonella*. Dry heating at 75°C affected the bacteriostatic ability of reconstituted egg white to a greater extent than did dry heating at 67°C. This loss of bacteriostatic ability could be attributable to the thermal denaturation of ovotransferrin, resulting in a reduction in its activity as an iron chelator. However, dry heating at 75°C resulted in improved functional properties. Ultimately, no complete compromise between better functional quality and the preservation of the bacteriostatic ability of egg white after reconstitution is possible. These results underline the importance of using hygienic conditions when working with egg white powder, especially with powder subjected to high-temperature treatments.

Where required, salt or sugar shall be added prior to pasteurisation. Salt and sugar shall be sieved before adding. Pasteurised product must be stored separately from raw product to prevent any risk of cross-contamination:

- Storage temperatures shall be achieved as rapidly as possible after processing. Blast chillers and freezers are recommended to achieve desired storage temperatures.
- All refrigerators, cool rooms and freezers shall be fitted with thermometers. Temperatures shall be recorded twice daily. It is recommended that automatic temperature recording devices are installed.
- Products to be frozen shall be blast frozen. Products shall be frozen within 24 hours. Storage shall be at −18°C, or below.
- Liquid egg products shall be stored at less than 5°C.
- Dried egg products shall be stored in a cool dry store (Australian Egg Corporation Limited, 2005a,b).

The egg pasteurisation process is summarised in Table 6.17.

6.2.11 Packaging

Egg product shall be packed in either recycled clean containers, or new containers or bags. Egg product shall be filled into containers on a closed line system. Large vats shall be filled by means of a pipe inserted

Table 6.17 Egg pasteurisation conditions.

Liquid egg product	Minimum temperature to be retained at (°C)	Minimum time to be retained for (minutes)	Maximum temperature to be cooled to (°C)	Other requirements
(i) Liquid egg or mixture of liquid yolk and liquid white	64°C	2.5 minutes	<5°C	
(ii) Liquid yolk	60°C	3.5 minutes	<5°C	
(iii) Liquid white	55°C	9.5 minutes	<5°C	
(iv) Egg white mix	55°C	9.5 minutes	<5°C	Produced from liquid egg white which has been pasteurised in accordance with (iii)
(v) Sugared/salted yolk	62°C	3.5 minutes	<5°C	

through a lid. When similar containers such as bags are filled, it is important that the operator does not contaminate the product with his/her hands. Filled containers shall be sealed immediately and then taken to the appropriate area (cool room, freezer or dry store) for storage.

6.2.12 Distribution

The vehicles and containers for transport of this type of egg product shall be designed and equipped so that the product temperatures are maintained during the transportation of the product (below 5°C for liquid egg and −18°C for frozen product):

- Tankers and mobile containers shall be cleaned, rinsed and then sanitised as soon as practicable after emptying and re-cleaned and sanitised before being refilled.
- Pipes, connections and valves used for the filling and discharge of the liquid egg shall be of a suitable design and shall be adequately cleaned and sanitised after use and before reuse.

6.2.13 Labelling

Every consignment of egg products leaving a processing establishment needs to be labelled. The storage temperature, batch number, use by/best before date and name and address of the manufacturer shall be clearly labelled on the product packaging.

6.3 METHODS TO DETERMINE EGG QUALITY IN PRODUCTION

Near-infrared reflectance spectroscopy (NIRS) is widely applied for quantitative analysis of chemical constituents such as protein content, moisture and fats in cereals, animal feeds, fats, meat and milk, as well as carbohydrates in fruit juices and alcohol in beverages (Burns and Ciurczak, 1992).

Applications of NIRS for the prediction of functional properties and quality variables in foods have also emerged (Berzaghi *et al*., 2005). Furthermore, discriminant analysis makes it possible to use NIRS for the identification and control of sample purity/quality.

Dalle Zotte *et al*. (2005) used NIRS to predict the physicochemical composition of freeze-dried egg yolk samples from laying hens fed with four different diets. Beside the control (C), the other three diets were enriched with different sources of *n*−3 PUFA: marine origin (NF), extruded linseed (EL) and ground linseed (GL). Furthermore, NIRS was used to classify the yolks according to hens' feeding regime.

Partial least squares (PLS) discriminant analysis was developed to differentiate the yolks, which originated from hens fed with the different diets. All the yolks from hens fed the C and the NF diets, and 98.6% of the two linseed diets, were correctly classified. pH, cholesterol and CIE colour parameters were not successfully predicted; the latter because the visible region was not scanned and this suggests that colour attributes cannot be predicted from NIR spectra alone. It was concluded that NIRS could be used both for estimation of chemical composition in nutritional experiments and as a screening analytical control technique for *n*−3 PUFA enriched eggs.

Direct sample introduction (DSI) or 'dirty sample injection' is a rapid, rugged and inexpensive approach to large volume injection in gas chromatography (GC) for semi-volatile analytes such as pesticides. DSI of complex samples such as eggs requires a very selective detection technique, such as tandem mass spectrometry (MS-MS), to determine the analytes among the many semi-volatile matrix components that also appear (Lehotay *et al*., 2001). In DSI, the non-volatile

matrix components that normally would contaminate the GC system in traditional injection methods remain in a disposable micro-vial, which is removed after every injection.

This analytical procedure involved the following: (i) weighing 10 g of egg in a centrifuge tube and adding 2 g of NaCl and 19.3 mL of acetonitrile (MeCN); (ii) blending for 1 minute using a probe blender; (iii) centrifuging for 10 minutes; and (iv) analysing 10 μL (5 mg of egg equivalent) of the extract using DSI/GC/MS-MS. No sample cleanup or solvent evaporation steps were required to achieve quantitative and confirmatory results with < 10 ng/g detection limits for 25 of 43 tested pesticides from several chemical classes. The remaining pesticides gave higher detection limits due to poor fragmentation characteristics in electron impact ionisation and/or degradation. Analysis of eggs incurred with chlorpyrifos-methyl showed a similar trend in the results as a more traditional approach.

6.4 CONCLUSIONS

Past efforts to control *S. enteritidis* have been largely reactive and have not succeeded in preventing contamination of eggs. Currently, hens or eggs that test positive for *S. enteritidis* are diverted to processing plants, where the bacteria are destroyed by thermal processes. Unfortunately, egg production environments cannot be made sterile, and only a small fraction of poultry houses, hens and eggs can actually be tested. For these reasons, it is virtually impossible to produce eggs with complete assurance that they are free of *S. enteritidis* bacteria. Therefore, efforts to control *S. enteritidis* need to be proactive, focusing on risk reduction and prevention. Food safety experts and the food industry agree that the best food safety system available for preventing foodborne illness is the HACCP system (http://pubs.cas.psu.edu/FreePubs/pdfs/AGRS72.pdf).

As a concluding remark, it could be said that the implementation of ISO 22000 is expected to improve considerably the performance of the egg sector particularly in view of the occurrence and severity of *Salmonella*. The egg poisoning incidents due to the latter are anticipated to undergo a drastic decrease; thanks to the introduction of PRPs and novel detection techniques.

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7
Seafood

Ioannis S. Arvanitoyannis and Theodoros H. Varzakas

7.1 INTRODUCTION

Seafood is now a widely traded global commodity. Total world exports of fish products amount to some $45 billion per year (average 1996–1999) (FAO, 2003b). Coffee, tea, cocoa and bananas (common examples of internationally important agricultural goods) had a combined total $38 billion per year in the same period, while the total export value for bovine meat was $14 billion per year in the same period (FAO, 2003c). Indeed, it is not only the total import/export value that is impressive; it is also the number of market participants. Nearly 200 countries and territories participate in seafood trade (FAO, 2003a); no other commodity approaches such a market breadth.

Because of the increasingly global market for seafood products, and projected increased demand for fish, consumers are likely to face increased exposure to foodborne risks from marine-based products. Wide variation in sources of supply suggests the difficulties in tracing sources of risk outside of tightly controlled supply systems. The challenge is to balance the need for publicly mandated consumer protection with the new innovations in retailing, quality control and contracting systems.

The globalisation of fish trade, coupled with technological developments in food production, handling, processing and distribution, and the increasing awareness and demand of consumers for safe and high-quality food have put food safety and quality assurance high in public interest and made it a priority for many governments. Consequently, many countries have tightened food safety controls, imposing additional costs and requirements on imports. As early as 1980, there was an international drive towards adopting preventative hazard analysis and critical control point (HACCP)-based safety and quality systems. More recently, there has been a growing awareness of the importance of an integrated, multidisciplinary approach to food safety and quality throughout the entire food chain. Implementation of this approach requires an enabling policy and regulatory environment at national and international levels with clearly defined rules and standards, establishment of appropriate food control systems and programmes at national and local levels, and provision of appropriate training and capacity building (Ababouch, 2006).

Global fish production is very significant for the global food trade and food security, providing more than 15% of total animal protein supplies. It averaged 128.7 million metric tonnes (MMT) during the period 1998–2003, with a record high of 133.0 MMT in 2002 (Table 7.1). About 38% of world fish production enters international trade and around 50% (in value terms) of this trade originates in developing countries.

The USA, the European Union and Japan import some 80% (in value) of the fish traded internationally. With increasing international fish trade and further globalisation, there is a greater risk of cross-border transmission of infectious agents, which can lead to an increased risk to human health and significant implications for international trade. This requires a more fully harmonised global approach to assure fish safety and quality while avoiding unfair trade practices and disguised technical barriers to trade (Ababouch, 2006).

In fisheries, there are five broadly defined needs on which a strategy in support of a food chain approach to food safety should be based:

- Fish safety and quality from a food chain perspective should incorporate the three fundamental components of risk analysis – assessment, management and communication.

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Table 7.1 Examples of food-associated outbreaks of illness caused by micro-organisms.

Food	Country	Micro-organism	Incidence	References
Raw shellfish	UK	*Salmonella*	11	Bell and Kyriakides (2002)
Crab and crab products	USA	*Salmonella*	11	Heinitz *et al.* (2000)
Raw crustaceans other than crab	USA	*Salmonella*	369	Heinitz *et al.* (2000)
Dried/salted seafood	USA	*Salmonella*	25	Heinitz *et al.* (2000)
Smoked fish/seafood	USA	*Salmonella*	10	Heinitz *et al.* (2000)
Finfish/skin fish	USA	*Salmonella*	249	Heinitz *et al.* (2000)
Prepared ready-to-eat seafood	USA	*Salmonella*	71	Heinitz *et al.* (2000)
Molluscs, ready-to-eat, out-of-shell	UK	*Salmonella*	4	Little *et al.* (1997)
Raw fish	Denmark	*Listeria monocytogenes*	33	Norrung *et al.* (1999)
Smoked seafood and seafood salad	USA	*Listeria monocytogenes*	229	Gombas *et al.* (2003)
Crawfish (raw, whole)	USA	*Listeria monocytogenes*	3	Thimothe *et al.* (2002)
Seafood (hake, mackerel, squid, mussel)	Argentina	*Listeria monocytogenes*	3	Laciar and de Centorbi (2002)
Cooked, ready-to-eat, out-of shell molluscs	UK	*Listeria monocytogenes*	221	Little *et al.* (1997)
Cold-smoked salmon	Denmark	*Listeria monocytogenes*	40	Jorgensen and Huss (1998)
'Gravad' salmon and halibut	Denmark	*Listeria monocytogenes*	25	Jorgensen and Huss (1998)
Heat-treated seafood	Denmark	*Listeria monocytogenes*	12	Jorgensen and Huss (1998)
Prepared seafoods	Spain	*Listeria monocytogenes*	2	De Simon and Ferrer (1998)
Preserved fish products – not heat treated	Denmark	*Listeria monocytogenes*	35	Norrung *et al.* (1999)
Frozen, smoked mussels – imported	Korea	*Listeria monocytogenes*	3	Baek *et al.* (2000)
Smoked mussels	New Zealand	*Listeria monocytogenes*	4 (2 deaths)	Baker *et al.* (1993)
Imitation crabmeat	Canada	*Listeria monocytogenes*	2	Farber *et al.* (2000)
Corn and tuna salad	USA	*Listeria monocytogenes*	1566	Aureli *et al.* (2000)
Kapchunka (dry-salted, air-dried, uneviscerated whole white fish)	USA and Israel	*Clostridium botulinum*	8 (1 death)	Telzak *et al.* (1990)
Canned salmon	UK	*Escherichia coli*	47	Riley *et al.* (1983)

- Traceability from the primary producer (including animal feed and therapeutants used in aquaculture), through post-harvest treatment, processing and distribution to the consumer must be improved.
- Harmonisation of fish quality and safety standards, implying increased development and wider use of internationally agreed upon, scientifically-based standards, is necessary.
- Equivalence in food safety systems – achieving similar levels of protection against fishborne hazards and quality defects whatever means of control are used – must be further developed.
- Increased emphasis on risk avoidance or prevention at source within the whole food chain – from farm or sea to plate – including development and dissemination of good aquaculture practices, good manufacturing practices (GMPs) and safety and quality assurance systems (e.g. HACCP), is necessary to complement the traditional approach to fish safety and quality management based on regulation and control (Ababouch, 2006).

Seafoods may harbour a number of biological, chemical and physical hazards, the most prevalent of which are biogenic amines, biotoxins, pathogenic bacteria and viruses. Some of the largest food poisoning outbreaks have been associated with seafoods. In 1991, more than 300,000 contracted hepatitis A in Shanghai in which there were nine deaths (Tang *et al.*,

1991). Around the same time, cholera caused more than 400,000 illnesses and more than 4000 deaths in Peru; the lightly fermented fish, ceviche, was thought to be a major vehicle (Wolfe, 1992).

Changes in the volume and direction of international trade in seafood and our understanding that most of seafoodborne health risk comes from the environment have created a need to expand risk mitigation foci from products/processing inspection to more broadly including a global perspective (both in terms of production and global coastal waters) (Yasuda and Bowen, 2006). Embracing the concept of a chain of custody/product, traceability is proposed as a core concept in ensuring access to information essential to a comprehensive view of seafood risk mitigation. Useful information needs to be collected, compatible, consistent and connected along the chain of custody. Activities of various regulatory agencies need to be organised, taking into consideration information requirements of agencies and stakeholders along the chain. A product identity system, which will enable retrieval of information collected along the chain of custody, must be established, (e.g. the EAN.UCC guidelines).

Recent development in information technologies, such as bar coding, makes it possible to introduce such a system. The chain framework can be used for two related organisational efforts. First, it can be used to link the various information acquisition and management efforts that presently exist (or need to be developed). Second, it can be used as a 'test-bed' to determine the degree to which the present regulatory environment represents well our emerging understanding of seafood production and markets.

Several issues relating to the nature and role of information need to be better understood and addressed. Indeed, if stakeholders along the chain of custody are to be able to use information collected along the chain, four conditions need to be met. First, useful information needs to be collected. Second, information needs to be compatible between countries. Third, information must be consistent. Fourth, various pieces of information need to be connected along the chain of custody so that people can use the information to deal with specific product flows (Yasuda and Bowen, 2006).

Exports of fish products are very important for the Sultanate of Oman to diversify sources of income and achieve higher standards of living for fishermen. In the past government regulations and support were sufficient to reach markets such as the European Union and the USA. During the last decade, however, there has been more focus on the application of more stringent quality regulations according to international norms namely HACCP. The Oman situation is used as an example of the way in which implementation of HACCP can help develop an international export market and thus how it is applicable to other countries. Zaibet (2000) provides an overview of international and national fish market regulations and the development of seafood regulations in Oman. An empirical framework was also developed to investigate empirically the relation between the adoption of international quality control procedures and success in export markets using an export penetration index. The paper findings show that up to 1998, Oman fish quality regulations differed in scope and objectives from HACCP. For instance, there was no requirement of plant-level quality management system equivalent to HACCP. Moreover, Oman regulations were based on regular inspections by government agents, whereas HACCP is a system-based approach aiming at reducing repeated inspections. Empirical results support the hypothesis put forward; variables reflecting on the quality of fish products, that is, HACCP and sanitation, were found to be positively correlated to the export index.

Cold-smoked fish products, although amongst the highest concern products based on hazard analysis and risk assessment considerations relating to the potential for *Listeria monocytogenes* to be present, have an excellent food safety record with few outbreaks involving this organism attributed to these traditional products (Bell and Kyriakides, 2005). *Listeria* species do not appear to cause infections in fish and do not have a natural reservoir in fish. However, a variety of surveys have shown that they are present in river sediments and water, both fresh and seawater, and therefore may be present in the raw fish as a contaminant from the aquatic environment (Ben Embarek, 1994). The examples of food-associated outbreaks of illness caused by micro-organisms are given in Table 7.1.

7.2 HAZARDS

Health hazards in seafood can be roughly classified into two categories: pre-harvest and post-harvest risks. Pre-harvest risks are those originating in the environment. These include chemicals accumulated in fish tissues in the environment, 'natural' toxins and pathogenic micro-organisms.

Agents such as *Vibrio parahaemolyticus*, ciguatera toxin and paralytic shellfish toxin can be regarded as solely environmental in their origin. On the other hand, risks are added through the various production and transportation processes after fish are harvested. These include risks from chemicals added and

pathogens introduced or incubated through product processing.

Various efforts (all less than satisfying) have attempted to determine the aetiology of seafoodborne illness. For example, from January 1997 to August 2002, the Commonwealth of Massachusetts, USA, officially recorded 169 seafoodborne illness cases (Massachusetts Department of Public Health, 2002). The cases (33) caused by environmental agents such as ciguatera, paralytic shellfish poisoning and *V. parahaemolyticus* constituted nearly a third of the cases caused by known agents. Furthermore, according to CDC's data in 1997, ciguatera toxin caused 42% of seafood-related outbreaks (GAO, 2001a). Furthermore, an FDA assessment on the risk from *V. parahaemolyticus* estimated 4750 cases per year with a range from 1000 to 16,000 cases caused by this environmental pathogen (FDA, 2000). When this estimate is compared with the reported figure of 61 *Vibrio* spp. infections in a sample population of 29.5 million in the USA (10.5% of the US population), it is clear that current disease statistics underreport the extent of seafoodborne illnesses (CDC, 2001). While these examples hold little meaning within a global market of a size and diversity previously described, they are generally consistent with other case studies and data drawn from other states and countries.

Okadaic acid and dinophysistoxins are produced by some marine unicellular algae from plankton and also benthic microalgae and may accumulate in shellfish. These phycotoxins are involved in a gastrointestinal syndrome called diarrhetic shellfish poisoning (DSP), which occurs in humans after consumption of bivalve molluscs. Thousands of cases of human poisonings in Europe were caused by consumption of toxic shellfish during the past decade. The rapid detection and the reliable determination of the main phycotoxins implicated in DSP are a major concern for governmental institutions in charge of the sanitary control of seafood safety. Analytical procedures for the detection and determination of DSP toxins can be classified as: bioassays, biochemical methods including immunoassays, or physicochemical methods. Although a large number of methods have been developed, none has been officially validated. A complete panel of tools for DSP toxin analysis should include screening, investigation and confirmation methods. Fremy *et al.* (1999) present a compilation of recent developments and optimisations of these methods.

The occurrence of various *Vibrio* species in water, sediment and shrimp samples from multiple shrimp farm environments from the east and west coast of India was studied. The relative abundance was higher in west coast farms (ca. 10^4 cfu/mL water) when compared to the east coast (ca. 10^2 cfu/mL water). *Vibrio alginolyticus* (3–19%), *V. parahaemolyticus* (2–13%), *V. harveyi* (1–7%) and *Vibrio vulnificus* (1–4%) were the predominant *Vibrio* species identified by standard biochemical testing (Gopala *et al.*, 2005). In some cases, *Vibrio cholerae* could be found, but all isolates were negative for the cholera toxin (ctx) gene that is associated with choleragenic strains. The biochemical identification of *V. parahaemolyticus*, the other human pathogen among the species mentioned above, was confirmed by PCR (polymerase chain reaction) targeting the toxR gene and a 387 bp chromosomal locus specific for this species. Furthermore, the presence of the virulence-associated tdh (thermostable direct haemolysin) and trh (TDH-related haemolysin) genes in the *V. parahaemolyticus* isolates was also detected by PCR. Only two out of 47 isolates were tdh positive and one contained the trh gene. However, since *V. cholerae*, *V. parahaemolyticus* and *V. vulnificus* species are recognised as a major cause of seafoodborne illness, it is important to pay attention to post-harvest handling and adequate cooking.

In the seafood area, Lindquist and Westoo (2000) have published a quantitative risk assessment for *L. monocytogenes* in smoked salmon and trout in Sweden. The results of an FAO expert consultation on *L. monocytogenes* in fish products have been published (Farber, 2000). Risk assessments of *V. parahaemolyticus* in raw molluscan shellfish and *L. monocytogenes* in seafoods have been made by the US food and health regulatory bodies (FDA/FSIS, 2001a,b).

As part of a semi-quantitative risk assessment of ten seafood hazard/product combinations, a risk assessment tool was used to generate a Risk Ranking (Sumner and Ross, 2002). The tool is software in a spreadsheet format and provides a risk estimate, which is scaled between 0 and 100, where 0 represents no risk and 100 represents all meals containing a lethal dose of the hazard. Based on their ranking, seafoods in Australia fell into three risk categories (a) <32, (b) <32–48 and (c) >48. Hazard/product pairs with ranking <32 included mercury poisoning (relative risk [RR] = 24), *Clostridium botulinum* in canned fish (RR = 25), or in vacuum-packed cold-smoked fish (RR = 28), parasites in sushi/sashimi (RR = 31), viruses in shellfish from uncontaminated waters (RR = 31), enteric bacteria in imported cooked shrimp (RR = 31) and algal biotoxins from controlled waters (RR = 31). It should be noted that there have been no documented cases of foodborne illness from any of the above hazard/product pairings in Australia. Those

with rankings 32–48 included *V. parahaemolyticus* in cooked prawns (RR = 37), *V. cholerae* in cooked prawns (RR = 37), *L. monocytogenes* in cold-smoked seafoods (RR = 39), scombrotoxicosis (RR = 40), *V. vulnificus* in oysters (RR = 41), ciguatera in the general Australian population (RR = 45), *L. monocytogenes* in susceptible (RR = 45) and extremely susceptible populations (RR = 47) and enteric bacteria in imported cooked shrimp eaten by vulnerable consumers (RR = 48). Almost all the hazard/product pairs in this category have caused the outbreaks of food poisoning in Australasia. Those hazard/product pairs with rankings >48 included ciguatera from recreational fishing in susceptible areas (RR = 60), viruses in shellfish from contaminated waters (RR = 67) and algal biotoxins from uncontrolled waters in an algal event (RR = 72). There have been significant (>100 cases) food poisoning incidents involving viruses and biotoxins in shellfish, while ciguatera poisoning is prevalent among coastal communities in Australia's warmer waters (Sumner and Ross, 2002). Although this ranking approach is quite interesting, the position of the boundaries between these categories for example 'parasites in sushi/sashimi (RR = 31), viruses in shellfish from uncontaminated waters (RR = 31), enteric bacteria in imported cooked shrimp (RR = 31) and algal biotoxins from controlled waters (RR = 31)' is rather vague.

Outbreaks of listeriosis caused by consumption of ready-to-eat seafood, including cold-smoked fish, smoked mussels and imitation crabmeat, have been reported worldwide, for example in Sweden (Ericsson *et al*., 1997), New Zealand (Brett *et al*., 1998), Canada (Farber *et al*., 2000) and Denmark (Norrung *et al*., 1999).

Reducing contamination of *L. monocytogenes* in seafood processing environments is an important step to prevent cross-contamination and ensure safety of ready-to-eat seafood products. Electrolysed oxidising (EO) water, generated from electrolysis of a diluted sodium chloride solution (0.05–0.2% NaCl), has been reported to contain strong antimicrobial activities against many pathogens, including *Escherichia coli* O157:H7, *Salmonella enteritidis*, *L. monocytogenes*, *Campylobacter jejuni*, *Enterobacter aerogenes* and *Staphylococcus aureus*.

The effects of EO water on reducing *L. monocytogenes* contamination on seafood processing surfaces were studied by Liu *et al*. (2006). Chips (5×5 cm^2) of stainless steel sheet (SS), ceramic tile (CT), and floor tile (FT) with and without crabmeat residue on the surface were inoculated with *L. monocytogenes* and soaked in tap or EO water for 5 minutes. Viable cells of *L. monocytogenes* were detected on all chip surfaces with or without crabmeat residue after being held at room temperature for 1 hour. Soaking contaminated chips in tap water resulted in small-degree reductions of the organism (0.40–0.66 log cfu/chip on clean surfaces and 0.78–1.33 log cfu/chip on dirty surfaces). Treatments of EO water significantly ($p < 0.05$) reduced *L. monocytogenes* on clean surfaces (3.73 log on SS, 4.24 log on CT and 5.12 log on FT).

Presence of crabmeat residue on chip surfaces reduced the effectiveness of EO water on inactivating *Listeria* cells. However, treatments of EO water also resulted in significant reductions of *L. monocytogenes* on dirty surfaces (2.33 log on SS and CT and 1.52 log on FT) when compared with tap water treatments. The antimicrobial activity of EO water was positively correlated with its chlorine content. The high oxidation–reduction potential of EO water also contributes significantly to its antimicrobial activity against *L. monocytogenes*. EO water was more effective than chlorine water on inactivating *L. monocytogenes* on surfaces and could be used as a chlorine alternative for sanitation purposes. Application of EO water following a thorough cleaning process could greatly reduce *L. monocytogenes* contamination in seafood processing environments.

The Danish regulatory policy on *L. monocytogenes* in foods is based on the principles of HACCP and was developed using a health risk assessment approach. The Danish policy focuses examinations and criteria for *L. monocytogenes* in ready-to-eat foods and is based on a combination of inspection and product testing. Based on current epidemiological information from several countries, a concentration of *L. monocytogenes* not exceeding 100 cfu/g of food at the time of consumption seems to represent a low risk to consumers. In Denmark, ready-to-eat foods have been placed into six categories where absence of *L. monocytogenes* in 25 g is required in foods heat treated in the final package and in heat-treated as well as preserved, non-heat-treated foods which can support growth within the shelf life (Norrung *et al*., 1999). This level is necessary in foods capable of supporting growth, in order not to exceed 100 *L. monocytogenes* per gram at the point of consumption. In heat-treated and preserved foods, which are not supportive of growth within the shelf life and for raw, ready-to-eat foods, a level below ten *L. monocytogenes* per gram is regarded as acceptable. A level between 10 and 100 *L. monocytogenes* per gram is not satisfactory and a level above 100/g is not acceptable.

In 1997 and 1998, more than 15,000 samples from different categories of food were examined (semi-quantitatively) for the presence of *L. monocytogenes*.

A significant difference can be seen in the number of samples containing more than 100 *L. monocytogenes* per gram, between different categories of foods (1997, $p = 0.001$; 1998, $p = 0.016$). In 1997, preserved meat products and preserved fish products and to a lesser extent vegetables and meat or vegetable mayonnaise were more likely to contain high numbers (i.e. above 100 cfu/g) of *L. monocytogenes* than other food categories. In 1998, preserved meat products, but also heat-treated meat products, vegetables and meat or vegetable mayonnaise had the highest frequency of samples with >100 *L. monocytogenes* per gram.

In a survey performed in 1994 and 1995 in Denmark, 1.3% of ready-to-eat food samples (heat-treated meat products, preserved meat and fish products) were found to be contaminated with *L. monocytogenes* at a level above 100 cfu/g (Norrung *et al.*, 1999). The samples included in this survey were primarily products produced by authorised companies and comprised mainly vacuum-packed products or products packed in modified atmosphere and with long shelf lives, typically above several weeks. The corresponding percentages of positive samples primarily processed in the retail outlets (heat-treated meat products, preserved meat and fish products) in 1997 and 1998 were 0.3 and 0.6%, respectively. The results suggest that ready-to-eat meat and fish products with extended shelf lives produced by authorised companies are more likely to contain high numbers (>100 cfu/g) of *L. monocytogenes* than retail products with a shorter shelf life (Norrung *et al.*, 1999).

Predictive microbiology provides a powerful tool to aid the exposure assessment phase of 'quantitative microbial risk assessment'. Using predictive models, changes in microbial populations on foods between the point of production/harvest and the point of eating can be estimated from changes in product parameters (temperature, storage atmosphere, pH, salt/water activity etc.). Thus, it is possible to infer exposure to *L. monocytogenes* at the time of consumption from the initial microbiological condition of the food and its history from production to consumption. Predictive microbiology models have immediate practical application to improve microbial food safety and quality, and are leading to development of a quantitative understanding of the microbial ecology of foods.

While models are very useful decision-support tools, it must be remembered that models are, at best, only a simplified representation of reality. As such, application of model predictions should be tempered by previous experience, and used with cognisance of other microbial ecology principles that may not be included in the model. Nonetheless, it is concluded that predictive models, successfully validated in agreement with defined performance criteria, will be an essential element of exposure assessment within formal quantitative risk assessment.

Sources of data and models relevant to assessment of the human health risk of *L. monocytogenes* in seafoods are identified by Ross *et al.* (2000). Limitations of the current generation of predictive microbiology models are also discussed. These limitations, and their consequences, must be recognised and overtly considered so that the risk assessment process remains transparent. Furthermore, there is a need to characterise and incorporate into models the extent of variability in microbial responses.

Histamine is a significant chemical hazard in fish. It is a biogenic amine produced during microbial decomposition of scombroid fish such as tuna and mackerel. It is derived from the bacterial decarboxylation of amino acid histidine, that is present in large amounts in fish of the Scombridae family and its presence is considered as a good indicator of temperature abuse and the state of GMPs adopted in the handling of such fish. A simple and rapid chemical method for determination of histamine in fish flesh is reported for use in seafood quality inspection laboratories (Patange *et al.*, 2005). Good recoveries (>91%) were obtained for histamine at spiking levels ranging 1–60 mg/100 g. The overall precision (relative standard deviation, %) in the new assay ranged from 2.61 to 9.63. The interaction between the imidazole ring and *p*-phenyldiazonium sulfonate was made the basis of a quantitative colorimetric method for estimation of histamine. The results of the new assay showed a high correlation ($R^2 = 0.999$) with the assay of Hardy and Smith (1976) in the recovery of histamine. The limit of detection was 1 mg/100 g for the new assay and was comparable with the existing methods. A concentration-based reference colour scale is provided for the determination of defect and hazard action levels set by the regulatory agencies. Visual comparison of colour intensity of test samples with standard concentrations in reference colour scale for determining these levels without the aid of a spectrophotometer was an important practical application for rapidly estimating histamine in fresh fish fulfilling one of the HACCP requirements. The assay was simple requiring no laborious treatments, and may be suitable for routine analysis in monitoring histamine in fish.

Histamine poisoning is one of the most common chemically induced seafoodborne illnesses reported in the United States today. The causative agents are biogenic amines, commonly produced by Gram-negative bacteria. Histamine is a naturally occurring compound

found in humans that serves as a cell messenger for regulating vascular and bronchial diameter as well as other normal bodily functions. It is chemically produced by decarboxylation of the amino acid histidine. Histamine is produced by one of two types of decarboxylase enzymes, a pyridoxal phosphate-dependent enzyme found in animals as well as Gram-negative bacteria and a pyruvoyl-dependent enzyme found in Gram-positive bacteria (Kamath *et al*., 1991).

Histamine (or scombroid) fish poisoning (HFP) is reviewed in a risk assessment framework in an attempt to arrive at an informed characterisation of risk by Lehane and Olley (2000). Histamine is the main toxin involved in HFP, but the disease is not uncomplicated histamine poisoning. Although it is generally associated with high levels of histamine ($\geq$50 mg/100 g) in bacterially contaminated fish of particular species, the pathogenesis of HFP has not been clearly elucidated. Various hypotheses have been put forward to explain why histamine consumed in spoiled fish is more toxic than pure histamine taken orally, but none has proved totally satisfactory. Urocanic acid, like histamine, an imidazole compound derived from histidine in spoiling fish, may be the 'missing factor' in HFP. *cis*-Urocanic acid has recently been recognised as a mast cell degranulator, and endogenous histamine from mast cell degranulation may augment the exogenous histamine consumed in spoiled fish. HFP is a mild disease, but is important in relation to food safety and international trade. Consumers are becoming more demanding, and litigation following food poisoning incidents is becoming more common. Producers, distributors and restaurants are increasingly held liable for the quality of the products they handle and sell. Many countries have set guidelines for maximum permitted levels of histamine in fish. However, histamine concentrations within a spoiled fish are extremely variable, as is the threshold toxic dose. Until the identity, levels and potency of possible potentiators and/or mast-cell-degranulating factors are elucidated, it is difficult to establish regulatory limits for histamine in foods on the basis of potential health hazard.

Histidine decarboxylating bacteria produce histamine from free histidine in spoiling fish. Although some are present in the normal microbial flora of live fish, most seem to be derived from post-catch contamination on board fishing vessels, at the processing plant or in the distribution system, or in restaurants or homes. The key to keeping bacterial numbers and histamine levels low is the rapid cooling of fish after catching and the maintenance of adequate refrigeration during handling and storage. Despite the huge expansion in trade in recent years, great progress has been made in ensuring the quality and safety of fish products. This is largely the result of the introduction of international standards of food hygiene and the application of risk analysis and HACCP principles.

The quality indices of Atlantic mackerel, hot smoked at core temperature not exceeding 60°C, containing 14–27 g salt and 580–670 g water per kilogram meat, were determined just after smoking and during storage (Kolodziejska *et al*. 2002). The aerobic plate count (APC) after smoking, chilling and packing in cardboard boxes was 0–12 cfu/25 cm^2 of the skin of the smoked fish and 10–240 cfu/g of flesh. It was 1.9 log cycles lower than that in the frozen raw material. At 2°C, the bacterial count on the fish surface and in the meat remained unchanged for at least three weeks. At 8°C after 14 days, the colony forming unit in the meat of smoked fish ranged from 1.8×10^2 to 1.6×10^7/g. The total count on the skin and just under the skin did not increase up to 21 days at 2 and 8°C. There was no statistically significant difference between the mean values of all evaluated sensory attributes of the smoked fish stored up to two weeks at 2 and 8°C. These results are from products produced at a smoking plant of very high hygienic standard, fulfilling all EC requirements, with quality assurance systems based on HACCP.

Cardinal and square root type models including or not interactions between environmental factors and probability models were evaluated by Augustin *et al*. (2005) for their ability to describe the behaviour of *L. monocytogenes* in liquid dairy products, cheese, meat and seafood products. Models excluding interactions seemed sufficient to predict the growth rate of *L. monocytogenes*. However, the accurate prediction of growth/no-growth limits needs to take interactions into account. A complete and a simplified form (preservatives deducted) of a new cardinal model including interactions and parameter values were suggested to predict confidence limits for the growth rate of *L. monocytogenes* in food. The new cardinal model including interactions is efficient in predicting confidence limits for the growth rate of *L. monocytogenes* and its growth probability in liquid dairy products, meat and seafood products. In cheese, the model was efficient in predicting the absence of growth of the pathogen. The suggested model can be used for risk assessment and risk management concerning *L. monocytogenes* in dairy, meat and seafood products (Augustin *et al*., 2005).

One hundred and ten samples of ready-to-eat, vacuum-packed, smoked and cold-salted fish products were collected from retail outlets in southern Finland during 1996 for examination of the occurrence and

level of *L. monocytogenes*. The samples originated from 12 producers. Positive samples with levels exceeding 100 cfu/g were encountered mainly in one of the producers (no. 8). Therefore, 200 samples from the plant and the products of this producer were studied during August–September 1996 and May–September 1997, as well as 55 samples from the six fish farms providing raw material fish to this plant, during September 1997–January 1998. The isolates were characterised by serotyping and pulsed-field gel electrophoresis (PFGE). *L. monocytogenes* was isolated in 20% (22/110) of the samples from the retail market, originating four from six producers (Johansson *et al*., 1999). Ten of these positive samples contained *L. monocytogenes* at >100 cfu/g (maximum 1.37×10^4 cfu/g). Seventeen per cent (5/30) of cold-smoked and 50% (16/32) of cold-salted rainbow trout samples were contaminated. Only one hot-smoked fish product (2%) was found to be positive by enrichment. Nineteen (86%) of the strains isolated from the retail samples belonged to serovar 1/2a and three (14%) to serovar 4b. In further studies, the production line of plant no. 8 was found to be contaminated. All the isolates prior to autumn, 1997, both in the products and at the production plant were serovar 1/2a; thereafter one strain of 4b and one of 1/2 (H-antigen untypeable) were isolated from the plant. The samples from raw material fish were all negative for *L. monocytogenes*. The samples from retail markets fell into seven PFGE types. Five and nine PFGE types, respectively, were found from the products and the plant of producer no. 8. PFGE type A was detected from the retail products of four producers and was also dominant among the isolates from production plant no. 8. PFGE type A was the only one found repeatedly from skinning, salting and slicing units as well as from products throughout the whole period. PFGE proved to be a powerful tool for studying contamination points and routes in the production plant. The implementation of measures based on HACCP programme resulted in a significant improvement such that *L. monocytogenes*-negative samples were produced at plant no. 8 from the beginning of January 1998 (Johansson *et al*., 1999).

Grey Allen *et al*. (2005) tried to detect and identify histamine-producing bacteria associated with standard industry practices during the harvesting, receiving and processing of mahimahi and yellowfin tuna in North Carolina. Twenty-nine composite samples were obtained from 18 mahimahi and 11 yellowfin tuna and analysed for their histamine content. No sample analysed exceeded 2 ppm histamine, the lower detection limit. Composite fish muscle and environmental samples were screened ($n = 386$) for the presence of histamine-producing bacteria. Twenty-six per cent (145) of 549 isolates selected on the basis of their morphological characteristics tested positive on Niven's media. Sixty-three Niven-positive isolates were Gram-negative, and 58 were Gram-positive. Of the 43 isolates tested further, five were confirmed as histamine producers, and all five produced at low levels (250 ppm in 48 hours at 15°C). Three Gram-negative and two Gram-positive isolates were identified as *Enterobacter cloacae* and *Staphylococcus kloosii*, respectively. This study revealed that Gram-negative bacteria might not be solely responsible for histamine production in at-risk fish. The confirmation of histamine-producing bacteria demonstrates the potential risk for histamine production. However, no detectable levels were found in the composite fish muscle samples analysed even though 60% of the yellowfin tuna harvested did not meet the US Food and Drug Administration's regulatory HACCP guidelines for temperature reduction. Therefore, no seafood safety risks were found under the standard industry practices observed in this study.

Aspergillus fumigatus is a well-known pathogenic fungus that is responsible for more than 80% of aspergillosis, especially in immunocompromised patients. A chemical study has shown that this strain was producing a major cytotoxic mycotoxin – gliotoxin (GTX) – when cultured in marine conditions (Gareis and Wernery, 1994). Gliotoxin (Fig. 7.1) is a tricyclic alkaloid, a member of the epipolythiodioxopiperazine family, in which the disulphide bridge is responsible for numerous biological activities (Waring and Beaver, 1996). A strain of *A. fumigatus* has been isolated from sediments of a mussel bed. When cultured in hyper saline conditions (with seawater), it produces a cytotoxic and immunosuppressive toxin, gliotoxin, which is excreted in an exudate. In order to know if this toxin could represent a risk for shellfish consumers, the bioaccumulation of gliotoxin in mussels has been investigated (Grovel *et al*. 2003). After 6 days of contamination, toxin accumulated in the meat of the mussels, at a level up to 2.9 mg/mg of extract weight, with a mode of contamination different to the classical digestive process described for a majority of marine toxins, but similar to the contamination mode of domoic acid.

Potential health hazards from aquaculture products arise either from contaminants that enter the fish during the process of farming (feed additives, drugs) or loss of quality due to inappropriate handling and processing (Chimatiro, 1998). Arsenic (As) is ubiquitous in the environment and hence human consumption of food and water results in chronic exposure to low levels of arsenic; however, the bioavailability and toxicity of arsenic depend largely on the chemical form

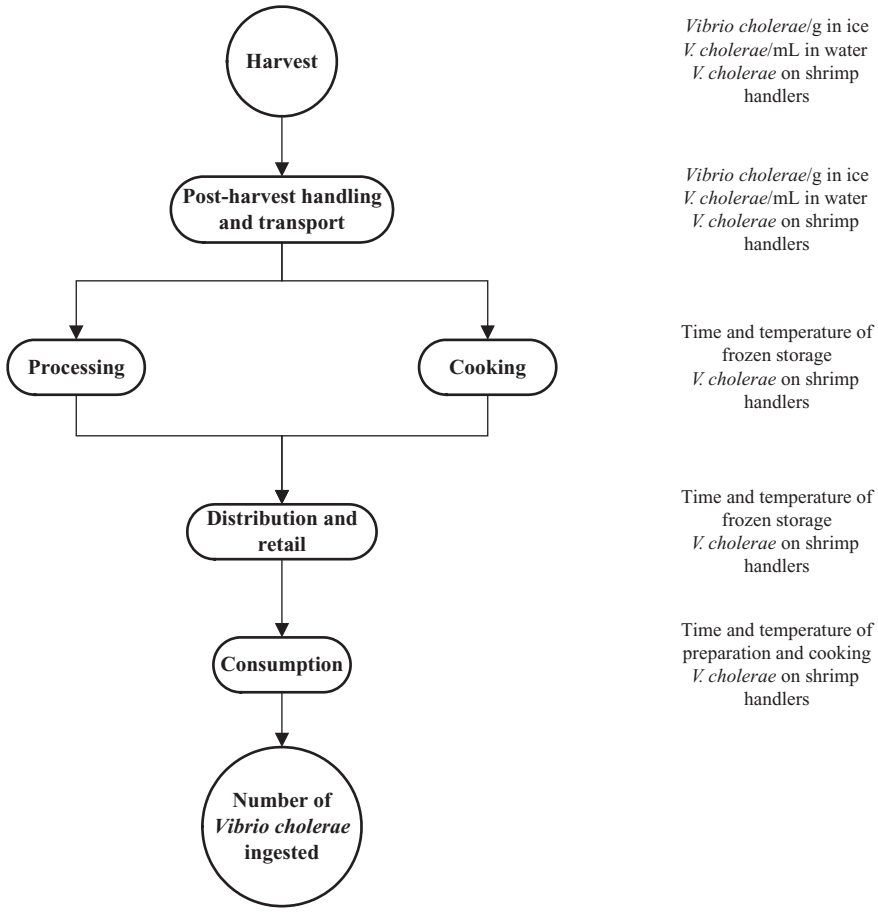

Fig. 7.1 Production-to-consumption pathway for exposure assessment of Vibrio cholerae in warm-water shrimp harvested and processed for international markets.

in which it is found. As(III) and As(V), which together constitute inorganic arsenic, are the most toxic species.

Moreover, specific studies have been conducted on levels of inorganic arsenic in seafood products (Munoz *et al*., 2000), but with the analyses being performed on the raw product. Total and inorganic arsenic contents were analysed in cooked seafood products consumed in Spain during the period July 1997–June 1998: hake, meagrim, small hake, anchovy, Atlantic horse mackerel, sardine, bivalves, crustaceans, squid, and salted cod by Devesa *et al*. (2001). Various cooking treatments were used (grilling, roasting, baking, stewing, boiling, steaming and microwaving). The results obtained were compared statistically with those found previously in the same raw products, and they showed that after cooking there was a significant increase in the concentration of total arsenic for salted cod and bivalves, and in the concentration of inorganic arsenic for bivalves and squid. The mean content of inorganic arsenic was significantly higher in bivalves than in any other type of seafood (Devesa *et al*., 2001).

For the Spanish population, the mean intake of total arsenic estimated on the basis of the results obtained in the study was 245 μg/day (Devesa *et al*., 2001). The intake of inorganic arsenic (2.3 μg/day) represents 1.7% of the World Health Organization provisional tolerable weekly intake, leaving an ample safety margin for this population, which has a very high consumption of seafood.

Minimisation of specific pollutants from US rainbow trout (*Oncorhynchus mykiss*) farms is motivated by regulatory requirements and corporate philosophy, but success in reducing the discharge of potential pollutants is dependent upon facility design, operation and financial commitment. In south central Idaho (USA), aquaculturists are subject to a Federal Clean Water

Act, which states the total maximum daily load to ensure a reduction in the effluent levels of total phosphorus (TP) and total suspended solids (TSS). Total effluent mass loads of TP must be reduced by 40% from a baseline established in 1991.

Effluent TSS limits, while not completely determined, were anticipated to need to be maintained at 3–5 mg/L. These reductions were achieved by 2004. Clear Springs Foods developed a waste minimisation programme using practices developed over a period of 12 years (MacMillan *et al*., 2003). These practices relied on application of disciplined best management practices (BMP) plan, optimisation of feeding practices, and use of low-phosphorus feed ingredients. Individual facility-specific BMP plans were developed using a HACCP-like approach. Corporate philosophy has embraced the importance of environmental stewardship because of its community benefit and long-term financial implications. These efforts resulted in a 40% reduction in effluent phosphorus from measured 1990 mass loads. Fish production volumes and fish quality have been maintained and increased costs limited.

It is well known that a wide variety of toxic chemicals are present in the world's oceans (Giam and Ray, 1987). Included among these are natural products as well as compounds of anthropogenic origin: marine toxins, inorganic and organic metals, petroleum and combustion-derived hydrocarbons, chlorinated pesticides, halogenated aromatic hydrocarbons (HAHs), and many others. These contaminants can be found bound to sediments, dissolved in water, in the sea-surface microlayer, and within various marine organisms, including marine animals used as food by humans and by other marine species. The highest concentrations of these chemicals are often found in urban harbours and other coastal areas. Experimental or epidemiological studies have shown that marine pollutants are capable of producing a variety of toxic effects in exposed organisms; some of the most common include neurotoxicity, immune dysfunction, reproductive and developmental effects, and cancer. Some of the compounds, such as the algal toxins sometimes found in shellfish, are primarily acutely toxic, while others, such as dioxins and polychlorinated biphenyls (PCBs), are of concern primarily because of their potential for causing chronic effects following long-term, low-level exposure (Hahn, 2002).

The presence of toxic chemicals in the marine environment presents two types of hazard: hazard to the health of humans exposed through consumption of contaminated seafood, and hazard to the health of marine organisms and ecosystems. The potential dangers of contaminated seafood are recognised by some consumers, though not by all (Burger *et al*., 1998; Tilden *et al*., 1997). For chemicals such as methyl mercury (MeHg) and PCBs, seafood represents the primary source of human exposure (Hahn, 2002).

The presence of toxic chemical contaminants in some marine organisms, including those consumed by humans, is well known. Monitoring the levels of such contaminants and their geographic and temporal variability is important for assessing and maintaining the safety of seafood and the health of the marine environment. Chemical analyses are sensitive and specific, but can be expensive and provide little information on the actual or potential biological activity of the contaminants. Biologically-based assays can be used to indicate the presence and potential effects of contaminants in marine animals, and therefore, have potential for routine monitoring of the marine environment (Hahn, 2002).

HAHs such as chlorinated dioxins, dibenzofurans, and biphenyls comprise a major group of marine contaminants. The most toxic HAHs (dioxin-like compounds) act through an intracellular receptor protein, the aryl hydrocarbon receptor, which is present in humans and many, but not all, marine animals. A toxic equivalency approach based on an understanding of this mechanism provides an integrated measure of the biological potency or activity of HAH mixtures. Biomarkers measured in marine animals indicate their exposure to these chemicals *in vivo*. Similarly, *in vitro* biomarker responses measured in cell culture bioassays can be used to assess the concentration of 'dioxin equivalents' in extracts of environmental matrices. Hahn (2002) has reviewed the types and relative sensitivities of mechanistically-based, *in vitro* bioassays for dioxin-like compounds, including assays of receptor-binding, DNA-binding and transcriptional activation of native (CYP1A) or reporter (luciferase) genes.

Cell culture bioassays are rapid and inexpensive, and thus have great potential for routine monitoring of marine resources, including seafood. Several such assays exist, or are being developed, for a variety of marine contaminants in addition to the dioxin-like chemicals. A battery of cell culture bioassays might be used to rapidly and sensitively screen seafood for the presence of contaminants of concern, including dioxin-like compounds as well as other contaminants such as natural toxins, hormonally active agents and heavy metals. Such a battery of mechanism-based, *in vitro* bioassays could be incorporated into monitoring efforts under HACCP programmes (Hahn, 2002).

Based on microbiological ecology, handling and processing practices and culinary preparations before consumption, seafood can be grouped according to

the risk and likelihood of causing disease as shown by Huss (1997a) and Huss *et al.* (2000):

- Molluscs (fresh and frozen mussels, clams, oysters in shell or shucked) and finfish – eaten raw or only slightly steamed.
- Fish raw materials, fresh and frozen fish and crustaceans, to be cooked before consumption.
- Lightly preserved fish products (NaCl <6% (w/w) in the water phase, pH > 5.0). This group includes salted, marinated, cold-smoked and gravad fish. Eaten without cooking.
- Heat-processed (pasteurised, cooked, hot-smoked) fish products and crustaceans (including pre-cooked, breaded fillets). Some products eaten with no additional cooking.
- Heat-processed (sterilised, packed in sealed containers). Often eaten with no additional cooking.
- Semi-preserved fish (i.e. NaCl > 6% (w/w) in water phase; or pH ~5.0) and preservatives (sorbate, benzoate, NO) may be added. This group includes salted and/or marinated fish and caviar. Eaten without cooking.
- Dried, dry-salted and smoke-dried fish. Usually eaten after cooking.

Huss (1997b) reported that the presence of pathogens in molluscs and the growth of *L. monocytogenes* in lightly preserved fish products are hazards which are presently not under control. In order to prevent growth and toxin production by *Cl. botulinum* when products are stored at abuse temperature, it is recommended that additional barriers (such as salting, smoking, lower a_w and pH) to growth are included in lightly preserved (e.g. cold-smoked salmon) and low-heat-treated (e.g. REPFEDS) products.

HACCP system is the preferred strategy in most quality assurance programmes and it is recommended that microbiological criteria are applied only as guidelines in the verification of the HACCP system – and not for official control purposes.

Fish and seafood are prone to rapid microbial spoilage, thus adequate care must be taken in drying of fish. The microbial load and its changes during drying and storage are important information in establishing a standard that will ensure food safety. In order to develop drying procedures leading to low-safety risk, it is relevant to determine the decimal reduction time (D value) and the thermal resistance constant (Z value) during a heating process to identify the effect of temperature on lethality. In the case of drying, microbial changes occurred due to the effects of heat and concentration process. Rahman *et al.* (2004) investigated the changes of endogenous bacterial counts in minced tuna during dry-heating (convection air-drying) and moist-heating (heating in a closed chamber) as a function of temperature. The D values for total viable counts decreased from 2.52 to 0.26 hours for moist-heating and 2.57 to 0.34 hours for dry-heating, respectively, when temperature was maintained constant within the range 60–140°C. In both cases, increasing temperature caused a significant decrease in D values ($p < 0.05$), whereas the effect of heating methods was not significant ($p > 0.05$). Thus' the heat resistance characteristics of micro-organisms in fresh tuna mince are not depended on the changing moisture content.

Generally, there are few problems with the occurrence of marine biotoxins in Danish mussels. When marine biotoxins occur in Denmark, they are usually only DSP toxins (Danish Veterinary and Food Administration, 2001). The toxin profile in Danish waters seems to be rather simple. Until 2001, the DSP-related toxins pectenotoxins, yessotoxins and azaspiracids were not detected in Danish mussels. However, the autumn of 2002 and winter of 2003 were rather unusual because there were much more DSP toxins than normal and several production areas were closed for weeks or months because of the continuous presence of DSP toxins in the mussels (van Apeldoorm *et al.*, 2006).

The situation in 2002 and 2003 in Denmark seemed to be similar to circumstances known from the Norwegian and Swedish Skagerrak and Kattegat coastlines where blue mussels typically were toxic during the same period, probably mainly caused by the presence of *Dinophysis acuta*.

It is known from Norway and Sweden that mussels typically are continuously toxic during the winter because of low metabolic rate of the mussels until the spring bloom when non-toxic phytoplankton becomes present as food for the mussels and the DSP toxins are eliminated from the mussels (Jorgensen and Jensen, 2004).

Data describing the distribution of DSP toxins in 13 consignments of Danish-produced blue mussels are reported by Jorgensen and Jensen, (2004). The content of DSP toxins was measured by a liquid chromatography coupled with a tandem mass spectrometry detection method, and mean levels in the 13 consignments varied from 58 to 243 μg/kg. The distributions of DSP toxins in the consignments were relatively homogenous as the relative standard deviation of the content varied from 7 to 19%.

Cholera, a serious dehydrating diarrhoeal disease endemic to a number of developing countries, is caused by the O1/O139 serovars of the bacterial pathogen *V. cholerae* (Reidl and Klose, 2002). Outbreaks of this disease can result from the periodic presence of this

pathogen in environmental water sources and the associated contamination of foods harvested from, or prepared using, this water (Albert *et al*., 1997).

Seafood is a recognised vehicle for the transmission of *V. cholerae* to humans and has been linked with outbreaks of cholera in a number of countries. Association of this pathogen with seafood generally occurs before harvesting from contaminated estuarine and coastal water. Prawns are harvested and processed in many developing countries in which cholera is endemic. Once harvested, prawns are chilled for local consumption or frozen either for local consumption or for export to other countries. It has been reported that *V. cholerae* can survive under chilled and frozen conditions for up to 4 weeks on shellfish such as prawns (Jeyasekaran and Ayyappan 2002; Nascumento *et al*., 1998). This survival is dependent on various factors such as the presence or absence of the chitin-containing carapace of the prawns, which reportedly has a cryoprotective effect for the pathogen.

In addition to freezing and chilling, the shelf life and quality of prawns may also be enhanced by using a regulatory approved sodium metabisulphite treatment to control melanosis or black spot on these products (Rotllant *et al*., 2002).

Sodium metabisulphite is traditionally used to control a non-microbiological spoilage symptom of prawns known as black spot. Januario and Dykes (2005) evaluated the effect of sodium metabisulphite, at levels currently used to control black spot, on the survival of *V. cholerae* on prawns during simulated commercial storage. Fresh prawns (*Penaeus monodon*) were divided into two batches, one of which was exposed to seawater while the other was treated with sodium metabisulphite (1%) in seawater. Two *V. cholerae* O1 strains were inoculated onto the prawns in separate experiments. Each of the batches was further subdivided and stored either under chilled conditions (1.5°C) for 14 days or under frozen conditions (−25°C) for 49 days. At appropriate time intervals, whole prawns were sampled and dilutions plated onto TCBS cholera medium to determine numbers of *V. cholerae*. Experiments were performed in triplicate and uninoculated controls were included. Results indicated a significant ($p < 0.05$) decrease in numbers of *V. cholerae* on both chilled (~4 log units) and frozen (~2 log units) prawns over the storage period. A significantly ($p < 0.05$) greater decrease in numbers of the pathogen (up to 1.8 log units) on chilled sodium-metabisulphite-treated, as compared to chilled untreated, prawns was apparent. Sodium metabisulphite had a negligible effect on numbers of *V. cholerae* on frozen prawns. The use of sodium metabisulphite could be optimised and used to enhance the safety of chilled seafood in cholera-endemic countries.

Sea turtle products (e.g. meat, adipose tissue, organs, blood, eggs) are common food items for many communities worldwide, despite national regulations in some countries prohibiting such consumption. However, there may be hazards associated with this consumption due to the presence of bacteria, parasites, biotoxins and environmental contaminants (Aguirre *et al*., 2006). Reported health effects of consuming sea turtles infected with zoonotic pathogens include vomiting, diarrhoea, and extreme dehydration, which occasionally have resulted in hospitalisation and death. Levels of heavy metals and organochlorine compounds measured in sea turtle edible tissues exceed international food safety standards and could result in toxic effects including neurotoxicity, kidney disease, liver cancer, and developmental effects in foetuses and children. The health data presented in this review provide information to health care providers and the public concerning the potential hazards associated with sea turtle consumption. Based on past mortality statistics from turtle poisonings, nursing mothers and children should be particularly discouraged from consuming all sea turtle products. It was recommended that individuals should choose seafood items lower in the food chain that may have a lower contaminant load. Dissemination of this information via a public health campaign may simultaneously improve public health and enhance sea turtle conservation by reducing human consumption of these threatened and endangered species.

Sea otters (*Enhydra lutris*) appear to be susceptible to a number of diseases and parasites that may have an anthropogenic origin, including toxoplasmosis, a zoonotic parasitosis. Molecular evidence has demonstrated that *Toxoplasma gondii* found in sea otters is similar to that found in humans and cats. Brucellosis is an important infectious disease of many terrestrial mammals, including humans. Members of the genus *Brucella* have recently been identified in several species of cetaceans and pinnipeds (Aguirre *et al*., 2006).

Levels of contaminants in fish are of particular interest because of the potential risk to humans who consume them. While attention has focused on self-caught fish, most of the fish eaten by the American public comes from commercial sources. Burger and Gochfeld (2005) sampled 11 types of fish and shellfish obtained from supermarkets and specialty fish markets in New Jersey and analysed them for arsenic, cadmium, chromium, lead, manganese, mercury and selenium. They tested the null hypothesis that metal levels do not vary among fish types, and it has to be considered

whether the levels of any metal could harm the fish themselves or their predators or pose a health risk for human consumers. There were significant interspecific differences for all metals, and no fish types had the highest levels of more than two metals. There were few significant correlations (Kendall tau) among metals for the three most numerous fish (yellowfin tuna, bluefish, and flounder), the correlations were generally low (below 0.40), and many correlations were negative. Only manganese and lead positively were correlated for tuna, bluefish and flounder. The levels of most metals were below those known to cause adverse effects in the fish themselves. However, the levels of arsenic, lead, mercury and selenium in some fish were in the range known to cause some sublethal effects in sensitive predatory birds and mammals and in some fish exceeded health-based standards. The greatest risk from different metals resided in different fish; the species of fish with the highest levels of a given metal sometimes exceeded the human health guidance or standards for that metal. Thus, the risk information given to the public (mainly about mercury) does not present a complete picture. The potential of harm from other metals suggests that people not only should eat smaller quantities of fish known to accumulate mercury but also should eat a diversity of fish to avoid consuming unhealthy quantities of other heavy metals. However, consumers should bear in mind that standards have a margin of safety.

Parasites are responsible for a substantial number of seafood-associated infections. The factor most commonly associated with infection is consumption of raw or undercooked seafood. Parasites readily identifiable from both consumable seafood and infected human beings include nematodes, trematodes, cestodes and protozoa. The salient features associated with seafood-related parasite infestations are discussed by Butt *et al*. (2004b). To provide a safe product for consumers, the seafood industry and the government both in the USA (Procedures for the safe and sanitary processing and importing of fish and fishery products, 1995, and Sustainable Fishery Act, 1996) and in European Union (Directives 91/67/EEC, 91/492/EEC, 91/493/EEC, 92/48/EEC, Decision 97/296/EC and Regulation [EC] No. 104/2000) and in Canada (Fish Inspection Act and Fresh Fish Marketing Act, 1985) (Arvanitoyannis *et al*., 2005) have undertaken specific measures, which include GMPs and HACCPs implemented by the government and regulatory agencies. Consumers should take common precautions including obtaining seafood from reputable sources especially if the seafood is to be consumed uncooked. Adequate cooking of seafood is the safest way of preventing related infections.

A range of conditions allows these infections to become established in endemic areas. Poor sanitation leading to faecal contamination of natural water sources used for fishing and intentional use of night soil (human excrement used as fertiliser) in aquacultural fish ponds lead to reservoirs of infection. In the life cycles of most digenetic trematodes, cercariae encyst in or on a second intermediate host, forming metacercariae. When the second intermediate host is eaten, the metacercariae excyst in the definitive host's intestinal tract, thus establishing an infection. Consumption of raw or lightly cooked fish or shellfish is responsible for transmission of infection to human beings. Proper cooking will effectively kill metacercariae (if the flesh becomes white or pale in colour and assumes a firm texture) (Adams *et al*., 1997). Freezing can be effective, but salting, smoking and marinating are unreliable in killing the metacercariae.

For example, about 1000 cases of anisakiasis are reported from Japan each year probably related to raw fish consumption (Sushi), whereas in the USA, where seafood is more often thoroughly cooked, only about 50 cases have been reported.

Anisakiasis is the human nematode infection most commonly associated with consumption of seafood. The species most commonly implicated is *Anisakis simplex*, followed by *Pseudoterranova decipiens* (Herreras *et al*., 2000; Piccolo *et al*., 1999). *A. simplex* is about 2 cm long and is extremely difficult to see within the fish musculature. In addition to many fish species anisakid parasites (*A. simplex* and *A. pegreffii*) have been reported in cephalopod species (particularly squid) from Japan, China and Spain (Butt *et al*., 2004b).

Three types of illnesses are associated with ingestion of seafood: allergic, toxic and infectious. While a large number of seafood-related illnesses fall into the first two categories, this review will focus on infectious illness resulting from the ingestion of seafood. Here, seafood is defined as both freshwater and seawater fish, including finfish and shellfish. Shellfish includes molluscs such as oysters, mussels, cockles, and clams, and crustaceans such as crabs, shrimps, and prawns. In one study from New York (Wallace *et al*., 1999) shellfish accounted for 64% of the seafood-related infectious outbreaks and finfish were implicated in 31%. It is a leading cause of gastroenteritis associated with consumption of raw shellfish, especially oysters (Berg *et al*., 2000).

Foodborne diseases cause an estimated 76 million illnesses in the USA each year. Seafood is implicated in 10–19% of these illnesses. A causative agent can be traced in about 44% of seafood-related outbreaks, viruses accounting for around half of these illnesses.

Although viruses are the most common cause of seafood-related infections, most hospitalisations and deaths are due to bacterial agents (Butt *et al*., 2004a).

A wide variety of viruses, bacteria and parasites have been implicated in seafood-related outbreaks, which are reported worldwide. The factor most commonly associated with infection is consumption of raw or undercooked seafood.

People with underlying disorders, particularly liver disease, are more susceptible to infection.

Hepatitis A infection caused the largest epidemic in Shanghai, China, in 1988, in which more than 288,000 people were infected after eating raw or improperly cooked clams. In the largest outbreak in Italy in 1996–1997, 11,000 people were infected. The most important risk factor in the primary cases was consumption of raw seafood, while person-to-person contact, perhaps between children, played a major part in secondary cases (Germinario *et al*., 2000). *V. parahaemolyticus* is the species most commonly associated with human disease, followed by *V. cholerae* non-O1, *Vibrio hollisae*, *Vibrio alginolyticus* and *Vibrio fluvialis* (Levine and Griffin, 1993). The predominant syndrome associated with vibrio infections is gastroenteritis, accounting for up to 80% of cases.

Many epidemics caused by *V. parahaemolyticus* have been reported. In an outbreak from the Pacific Northwest in 1997, 209 culture-confirmed cases of *V. parahaemolyticus* were identified. More than 80% of the infected people reported eating mollusc shellfish, with most of them having eaten raw oysters harvested from waters off the coast of British Columbia (CDC, 1998).

Mercury (Hg) has accumulated over many years in soil and it is continuously released to lakes and coastal waters. In addition, there is a global transport of Hg emissions leading to a significant contribution to the environmental mercury pool (Johansson *et al*., 2001). Hg biomagnifies in the aquatic food web as MeHg; hence, large predatory species have the highest concentrations (UNEP, 2002).

Bjornberg *et al*. (2005) studied the exposure to MeHg in 127 Swedish women of childbearing age with high consumption of various types of fish, using total mercury in hair and MeHg in blood as biomarkers. Fish consumption was assessed using a food frequency questionnaire (FFQ), including detailed information about consumption of different fish species, reflecting average intake during 1 year. They also determined inorganic mercury (I-Hg) in blood, and selenium in serum. The average total fish consumption, as reported in the FFQ, was approximately four times/week (range 1.6–19 times/week). Fish species potentially high in MeHg, included in the Swedish dietary advisories, were consumed by 79% of the women. About 10% consumed such species more than once a week, i.e. more than is recommended. Other fish species potentially high in MeHg, not included in the Swedish dietary advisories, were consumed by 54% of the women. Eleven per cent never consumed fish species potentially high in MeHg.

Bjornberg *et al*. (2005) found no statistical significant associations between the various mercury species measured and the selenium concentration in serum. Hair mercury levels exceeded the levels corresponding to the EPA reference dose of 0.1 Ag MeHg/kg body weight per day in 20% of the women. Thus, there seems to be no margin of safety for neurodevelopmental effects in the foetus, for women with high fish consumption unless they decrease their intake of certain fish species. Selenium is an essential, antioxidative trace element that has been shown to interact with both MeHg and I-Hg in experimental studies, and thereby be protective against Hg toxicity; however, the effect is not well documented in humans.

Commercial ice should be safe to consume and of the same quality as drinking water because it is ingested directly when added to juices and soft drinks or indirectly when used to refrigerate foods such as fish and seafood.

The relationship between contaminated water and human diseases emphasises the importance of a study to gain information about the hygienic conditions of commercial ice. Water from which ice originates must not have pathogenic bacteria that could remain viable during storage. When pathogenic micro-organisms enter the human body by ingestion of contaminated food or water, they can cause diarrheic illness. The most commonly found enteropathogenic organisms are Gram-negative bacilli of the Enterobacteriaceae (*Salmonella*, *Shigella*, *Yersinia* and enteropathogenic *E. coli*). Ice used for human consumption or to refrigerate foods can be contaminated with pathogenic micro-organisms and may become a vehicle for human infection. To evaluate the microbiological content of commercial ice and ice used to refrigerate fish and seafood, 60 ice samples collected at six different retail points in the city of Araraquara, SP, Brazil, were studied by Falcao *et al*. (2002). The following parameters were determined: total plate counts (37 and 4°C), most probable number (MPN) for total coliforms, faecal coliforms and *E. coli*, presence of *Salmonella* spp., *Shigella* spp., *Yersinia* spp., *E. coli*, *V. cholerae* and *Aeromonas* spp. Results suggested poor hygienic conditions of ice production due to the presence of indicator micro-organisms. Fifty strains of *E. coli* of different serotypes, as well as one *Y. enterocolitica* biotype 1, serogroup O:5,27 and phage type Xz (Ye 1/O5,27/Xz)

and one *Salmonella enteritidis* phage type 1 were isolated. *Aeromonas* spp., *Shigella* spp. and *V. cholerae* were not detected. The presence of high numbers of coliforms, heterotrophic indicator micro-organisms and pathogenic strains suggested that commercial ice and ice used to refrigerate fish and seafood may represent a potential hazard, depending on climate conditions, to the consumer.

E. coli is a common contaminant of seafood in the tropics and is often encountered in high numbers. The count of *E. coli* as well as verotoxigenic *E. coli* O157:H7 was estimated in 414 finfish samples composed of 23 species of fresh fish from retail markets and frozen fish from cold storage outlets in and around Cochin, India, by Thampuran *et al.* (2005). A total of 484 presumptive *E. coli* was isolated, and their indole–methyl red–Voges-Proskauer–citrate pattern was determined. These strains were also tested for labile toxin production by a reverse passive latex agglutination method and checked for *E. coli* serotype O157 by latex agglutination with O157-specific antisera. Certain biochemical marker tests, such as methylumbelliferyl-b-glucuronide (MUG), sorbitol fermentation, decarboxylase reactions, and haemolysis, which are useful for screening pathogenic *E. coli*, were also carried out. Results showed that 81.4% of the *E. coli* isolates were sorbitol positive. Among this group, 82% were MUG positive, and 14.46% of the total *E. coli* isolates showed human blood haemolysis. None of the isolates were positive for agglutination with *E. coli* O157 antisera nor did any produce heat-labile enterotoxin. This study indicates that typical *E. coli* O157 or labile toxin-producing *E. coli* is absent in the fish and fishery environments of Cochin (India). However, the presence of MUG and sorbitol-negative strains that are also haemolytic indicates the existence of aberrant strains, which require further investigation.

Polycyclic aromatic hydrocarbons (PAHs) are a large group of organic compounds that are formed during the incomplete combustion of organic substances. Experimental studies on animals show several adverse health effects, and their carcinogenicity and genotoxicity potential has attracted the most attention. The International Agency for Research on Cancer (IARC, 2006) determined that benzo[α]pyrene, benz[*a*]anthracene and dibenz[*a*,*h*]anthracene are probably carcinogenic in humans, while benzo[*b*]fluoranthene, benzo[*k*]fluoranthene, dibenz[*a*,*e*]pyrene, dibenz[*a*,*h*]pyrene, dibenz[*a*,*i*]pyrene, dibenz[*a*,*l*]pyrene, 5-methylchrysene and indeno[1,2,3-*c*,*d*]pyrene are possibly carcinogenic in humans.

The incomplete combustion of organic matter can occur spontaneously in nature (forest fires and volcanic eruptions), but the main source of environmental PAHs is human activities. Most come from fossil fuel combustion sources (such as automobiles, power plants, and residential heating), aluminium, iron and steel production, or refuse incineration (Directorate-General of Health and Consumer Protection, 2004).

Fontcuberta *et al.* (2006) reported on the concentrations of eight PAHs in food samples collected in the city of Barcelona (Catalonia, Spain) from 2003 to 2004. Food samples included meat products, fish (fresh and smoked), other seafood (cephalopods, crustaceans, and bivalves), vegetable oil and tea. Concentrations of benz[*a*]anthracene, benzo[*b*]fluoranthene, benzo[*k*]fluoranthene, benzo[*g*,*h*,*i*]perylene, benzo[α]pyrene, benzo[*e*]pyrene, dibenz[*a*,*h*]anthracene and indeno[1,2,3-*c*,*d*]pyrene were determined by reversed-phase high-performance liquid chromatography with fluorescence detection.

PAHs were detected in most tea samples (94%), which had the highest concentration of total PAHs (mean concentration 59 μg/kg). Other food groups with a high presence of PAHs were bivalves (present in 34% of the samples; mean value 2.7 μg/kg) and meat products (present in 13% of the samples; mean value 1.7 μg/kg). The PAHs detected most frequently were benzo[*e*]pyrene and benzo[*b*]fluoranthene. No sample had levels above current regulatory standards. Nevertheless, the frequent presence of PAHs in bivalves, tea samples and meat products, together with the fact that dietary sources are the main exposure to these carcinogenic compounds, suggests the need for some monitoring scheme to follow up on these trends.

The gross chemical composition and spoilage process of meat and fish are very similar. However, fish are much more perishable and, likewise, constitute better substrates for growth of pathogenic bacteria because of the pH difference (pH 5.5 and 6.8 for meat and fish, respectively) and lower glucose level of meat (Mossel *et al.*, 1995). Seafood can be categorised, in order of decreasing safety risk, as follows (Huss, 1992):

1. Molluscs (fresh and frozen mussels, clams, oysters in shell or shucked) often consumed with no additional cooking.
2. Lightly preserved fish products (NaCl 6% w/w in water phase, pH 5.0) – salted, marinated, cold-smoked and gravad fish – eaten without cooking.
3. Heat-processed (pasteurised, cooked, hot-smoked) fish products and crustaceans (pre-cooked, breaded fillets). Some of them can be consumed with no additional cooking.
4. Heat-processed (sterilised, packed in sealed containers), often eaten with no additional cooking.
5. Semi-preserved fish (NaCl 6% w/w in water phase, pH 5.0, preservatives like sorbate, benzoate, NO_2

may be added). This group includes salted and/or marinated fish and caviar. No cooking prior to consumption.
6. Dried, dry-salted, and smoked-dried fish. Usually eaten after cooking.
7. Fresh and frozen fish and crustaceans. Usually eaten after cooking
(Tzouros and Arvanitoyannis, 2000).

Microbiological limits for fresh fish have rarely been suggested (Garett, 1988). The results of surveys on industrially manufactured fish fillets have been presented elsewhere (Mossel *et al*., 1995). The predominant microflora in fresh finfish includes *Acinetobacter*, *Aerobacter*, *Aeromonas*, *Alcaligenes*, *Alteromonas*, *Bacillus*, *Clostridium*, *Corynebacterium*, *Flavobacterium*, *Micrococcus*, *Moraxella*, *Proteus*, *Pseudomonas* and *Vibrio* (Hsing-Chen, 1995). *Vibrionaceae*, *Salmonella*, *Campylobacter jejuni*, *Cl. botulinum*, *Shigella*, *S. aureus*, hepatitis A virus, non-A, non-B enteral hepatitis virus, Norwalk and related viruses, and helminths (*A. simplex*, *Diphyllobothrium*) are seafood agents responsible for diseases in healthy adults, while others can cause healthy problems to children, elderly people, immunosuppressed patients and those suffering from haemochromatosis and cirrhosis (*V. vulnificus*) (Williams and Jones, 1994). Finally, there are seafood micro-organisms of uncertain pathogenicity for humans (*Aeromonas hydrophila*, *Plesiomonas shigelloides*) (Ahmed, 1992).

Low-temperature storage (0–5°C) leads to dominance by psychotropic microflora consisting of *Shewanella putrefaciens*, *Photobacterium phosphoreum*, *Aeromonas* spp. and *Pseudomonas* spp., which cause spoilage of fresh fish. On the contrary, temperatures from 15 to 30°C favour the rapid increase of spoiling *Vibrionaceae*, *Enterobacteriaceae*, and Gram-positive organisms. By the end of storage life for iced temperature-water fish, *Pseudomonas* and *Shewanella* represent 80% of the final microflora. *Shewanella putrefaciens* is responsible for the production of trimethylamine, indole, scatole, putrescine, cadaverine and lower fatty acids, while Ps. Group I spp., Ps. Fragi and *Moraxella* spp. produce fruity odours (ethyl esters) and musty odours, respectively (Hanna, 1992). Metabolites produced by microbes such as volatile amines and fatty acids were extensively studied and it was suggested that they may be used as indicators of imminent spoilage (Wong and Gill, 1987).

For pathogenic *Vibrio* spp., the minimum infective dose is 105–106 cells, and for *A. hydrophila* and *P. shigelloides* it is even higher (Huss, 1997b). *L. monocytogenes* have been isolated from hot- and cold-smoked fish, cooked crabmeat, shrimp or lobster meat and even from surimi-based products (Fuchs and Nicolaides, 1994). It is rarely isolated from warm-water fish. Normal healthy people do not usually get infected with listeriosis from low numbers of cells (Huss, 1997b).

Histamine poisoning is often called scombroid fish poisoning. Histamine is produced by the action of histidine decarboxylase on histidine. Various micro-organisms (*Enterobacteriaceae* spp., *Pseudomonas*, *Clostridium perfringens*, *Vibrio* spp. and some Gram-positive halophilic and halotolerant micro-organisms) are responsible for this biochemical reaction. Histamine poisoning is caused by bacteria like *M. morganii*, *Klebsiella pneumoniae* and *Hafnia alvei*. Determination of histamine is possible by applying an enzymatic technique that screens food specimens and bacterial strains, is easy to conduct, is fast and is low cost (Rodriguez-Jerez *et al*., 1994).

Histamine levels in fish have been much studied because of the suspected connection between high levels of histamine and vasoactive 'scombroid' poisoning. Scombroid fish, including tuna, mackerel, bonito, and butterfly kingfish, contain high levels of free histidine, which is readily decarboxylated to histamine by a great variety of bacteria (Mossel *et al*., 1995). Although determination of histamine levels was shown not to be a reliable index of fish spoilage (Arnold and Brown, 1979), determination of the levels of all polyamines was found to provide an index of fish condition (Mietz and Karmas, 1977). Puffer fish poisoning is caused by 'tetrodotoxin', which is produced in buffer or globe fish by *Vibrios* of their normal microflora (Ahmed, 1992).

7.3 IRRADIATION

Irradiation or cold pasteurisation is a control measure in the production of many minimally processed foods such as poultry, meat and meat products, fish, seafood and fruits and vegetables. In these processes, irradiation may be a critical control point (CCP). It has the potential to eliminate vegetative forms of bacterial pathogens as well as parasites. It is a safe technology as recognised by FAO/WHO Codex Alimentarius Commission. Thirteen countries permit the irradiation of fish and seafood (Molins *et al*., 2001).

The *Pseudomonas* species are a dominant group of 'active spoilers' of seafoods. They can adapt to different environments while elaborating a range of enzymes that bring about the primary breakdown of the cell matrix under normal storage conditions. Such micro-organisms inhabit the surface, gills and intestinal tract of fish. They are psychrotrophic and can multiply in

refrigerated or frozen foods thereby reducing the shelf life and keeping quality of products (Banerjee and Black, 1986; Hobbs and Hodgkiss, 1982). The proteases produced by *Pseudomonas* species break down collagen in the tissues and are important in the spoilage and secondary microbial colonisation of foodstuffs, leading to changes in fish flesh. The presence and activity levels of such enzymes could therefore serve as a reliable 'index of spoilage', the detection of which might serve to analyse samples long before contamination and colonisation related characteristics become obvious.

The effects of *Pseudomonas* and the proteases it synthesises in seafoods rendering them unfit for consumption are not fully recognised. A sandwich enzyme-linked immunosorbent assay (ELISA) was developed wherein protease produced by *Pseudomonas* isolated from shrimp was used as antigen, and anti-protease IgG conjugated with alkaline phosphatase was the second antibody (Jabbar and Joishy, 1999).

Purified protease and seafood samples, naturally contaminated or artificially inoculated with *Pseudomonas*, were positive by ELISA. The conventional culture method took three days to complete, but ELISA detected *Pseudomonas* within 24 hours. The rapidity, simplicity and efficacy of this test make it useful for implementation of HACCP systems.

7.4 SHRIMPS

The shrimp farming industry is an important economic sector in many Asian countries, including Thailand, which is the world's top producer. During the 1980s the Thai shrimp farming sector developed rapidly, and has since 1993 produced 235,000–275,000 tonnes of cultured shrimps annually (FAO, 2001a).

The shrimp farming industry has been subject to criticism from environmentalists and scientists due to different negative effects on the environment (Flaherty *et al*., 2000; Naylor *et al*., 2000). Concern has been expressed regarding the use of chemicals in shrimp farms, and its potential impact on the environment and human health. Antibiotic use in Thai shrimp farms was further investigated, confirming that their use was extensive and often inappropriate.

Graslund *et al*. (2003) documented the use of chemicals and biological products in marine and brackish water shrimp farming in Thailand, the world's top producer of farmed shrimp. Interviews were conducted with 76 shrimp farmers in three major shrimp-producing regions, the eastern Gulf coast, the southern Gulf coast and the Andaman coast area. Farmers in the study used on average 13 different chemicals and biological products. The most commonly used products were soil and water treatment products, pesticides and disinfectants. Farmers in the southern Gulf coast area used a larger number of products than farmers in the other two areas. In the study, the use of more than 290 different chemicals and biological products was documented. Many of the pesticides, disinfectants and antibiotics used by the farmers could have negative effects on the cultured shrimps, cause a risk for food safety, occupational health, and/or have negative effects on adjacent ecosystems. Manufacturers and retailers of the products often neglected to provide farmers with necessary information regarding active ingredients and relevant instructions for safe and efficient use.

Examination of fresh and frozen shrimp revealed that spoilage is largely due to biochemical changes induced by the microbial population and to a lesser degree by enzymes and chemical compounds in shrimp. Farm raised shrimps are being processed as either block frozen or individually quick frozen.

One thousand two hundred and sixty-four samples of individually quick-frozen peeled and deveined raw and 914 samples of cooked ready-to-eat shrimp samples produced from farm raised black tiger (*Penaeus monodon*) obtained from a seafood unit working under HACCP concept were analysed by Mohamed Hatha *et al*. (1998) for total aerobic plate count (APC), coliform count, *E. coli*, coagulase positive Staphylococci and *Salmonella*. The overall bacteriological quality of the product was found to be good. Of the frozen raw shrimp, 96% of samples showed APC below 105 while 99% of the frozen cooked ready-to-eat samples showed APC less than 10^4. The APC ranged from 1.0×10^2 to 4.2×10^6 cfu/g in frozen raw shrimp and from 1.0×10^2 to 6.4×10^4 cfu/g in the frozen cooked shrimp. Prevalences of coliforms in raw shrimp and cooked shrimp samples were 14.4 and 2.9%, respectively. The coliform count in raw products ranged from 1.0×10^1 to 2.5×10^3 cfu/g and in the cooked products, from 1.0×10^1 to 1.8×10^2 cfu/g. Although all the cooked shrimp samples were free of coagulase positive staphylococci, *E. coli* and *Salmonella*, 1.0, 2.0 and 0.1% of the frozen raw shrimp samples, tested positive for coagulase positive *Staphylococci*, *E. coli* and *Salmonella*, respectively. The *Salmonella* strain was identified as *Salmonella typhimurium*. The results of the study highlighted the importance of implementation of the HACCP system in the seafood industry to ensure consistent quality of frozen seafood.

Outbreaks of cholera have been associated with consumption of seafood including oysters, crabs and shrimp (Oliver and Kaper, 1997). In the early 1990s, a pandemic of cholera swept through South and Central

America. The outbreaks seemed to begin in Peru, where there were more than 400,000 cases and 4000 deaths (Wolfe, 1992). Although no cases of cholera were associated with the consumption of commercial seafood, the industry, including shrimp exports, were negatively affected. The outbreak in the 1990s cost Peru US$770 million as a result of food trade embargos and adverse effects on tourism (WHO and FAO, 2005b). Similarly, the European Union banned importation of fish from eastern Africa as a result of an outbreak of cholera in the region (FAO, 1998).

Over the past two decades, the HACCP system has become an essential prerequisite for companies and countries wishing to participate in international trade. 'HACCP is a tool to assess hazards and establish control systems that focus on prevention rather than relying mainly on end-product testing' (CAC, 1997a,b). Currently, HACCP combined with good hygiene practices (GHPs), GMPs and sanitation standard operating procedures (SSOPs) constitute an integrated food safety management system, as practised by food (seafood) companies involved in international trade (FDA, 2001a).

Irrespective of whether the primary source is a marine, or an aquaculture, product the process has developed a number of CCPs for target pathogens, particularly those of faecal origin (e.g. *Salmonella*, *Shigella*, *V. cholerae*). These include:

- primary chilling immediately after harvest in an ice-water slurry on vessels and at harvest sites
- in cooked products, applying time–temperature regimes to give log reductions far in excess of likely contamination levels at sites of microbiological concern
- rapid chilling after cooking
- plate freezing, followed by frozen storage.

In addition, GHPs and GMPs for plant construction, water supply, ice production, temperature control and product flow from 'dirty' to 'clean' areas were adapted to conform with Codex requirements, and SSOPs exist for cleaning of food contact surfaces and for personal hygiene of handlers (CAC, 1997a,b).

According to the WHO definition, choleragenic *V. cholerae* O1 and O139 are the only causative agents of cholera, a water- and foodborne disease with epidemic and pandemic potential. Other serogroups (serovars) of *V. cholerae* are generally termed as non-O1 and non-O139 strains. They are generally non-choleragenic, usually cause a milder form of gastroenteritis than O1 and O139, and are normally associated with sporadic cases and small outbreaks rather than with epidemics and pandemics (Borroto, 1997; Desmarchelier, 1997; Kaper *et al*., 1995).

The risk assessment focuses primarily on *V. cholerae* O1, since very limited information was available for *V. cholerae* O139. The most important virulence factor associated with *V. cholerae* O1 and O139 is the cholera toxin. Cholera is exclusively a human disease and no animal species has been found consistently infected. The primary source of *V. cholerae* O1 and O139 is faeces of persons acutely infected with the organism (WHO and FAO, 2005b).

In the aquatic environment, strong association between levels of zooplankton and incidence of *V. cholerae* has been observed (Huq *et al*., 1983). Adhesion to chitin has been shown to influence strongly the ecology of *V. cholerae* (Nalin *et al*., 1979). Choleragenic *V. cholerae* has also been reported to attach to the hindgut of crabs (Huq *et al*., 1996) and it is noted that the hindgut of crustaceans is an extension of the exoskeleton and is lined with chitin.

There are very few records of isolation of *V. cholerae* O1 and O139 from shrimp. In laboratory experiments, adhesion and colonisation of *V. cholerae* O1 on shrimp and crab carapace were influenced by temperature and salinity (Castro-Rosas and Escartin, 2002). The shellfish most often associated with cholera cases are molluscan shellfish (oysters) and crabs. While oysters are consumed raw in many countries, crabs are generally cooked, though even after boiling crabs for up to 10 minutes or steaming for up 30 minutes, *V. cholerae* O1 may still retain viability (Blake *et al*., 1980).

V. cholerae O1 is highly sensitive to acidic environments and is killed within minutes in gastric juice with pH <2.4. Therefore, normochlorohydric individuals are less susceptible to cholera, provided the matrix does not protect the organisms. *V. cholerae* O1 is also highly sensitive to desiccation, indicating the need to use well-dried containers in product handling to minimise the transmission of cholera (ICMSF, 1996). The literature on survival of *V. cholerae* O1 in foods indicates different patterns of decline and longevity during storage at refrigeration and freezing temperatures (Felsenfeld, 1974).

Most studies indicate that, while decline occurs at refrigeration temperatures, a proportion of the bacterial population remains viable. Pesigan *et al*. (1967), starting with 10^5 cfu/g *V. cholerae* O1 in raw shrimp, recorded viable cells after 4–9 days at 5–10°C. Reilly and Hackney (1985) reported survival after 21 days at 7°C from an initial density of 7.8 log cfu/g. With respect to frozen storage, ICMSF (1996) reviewed literature from the 1930s that reported persistence for about 180 days and suggested that survival on fish was longer than on shrimp in 30 days at −20°C.

There is no evidence to show that marine shrimp caught by trawling in offshore waters with salinities

of about 30 ppt harbour choleragenic *V. cholerae* O1 and O139. Choleragenic *V. cholerae* occurs in waters with salinities between 0.2 and 20 ppt (Colwell and Spira, 1992). Studies conducted on freshly harvested marine shrimp indicated absence of choleragenic *V. cholerae* (Dalsgaard *et al.*, 1995). The production-to-consumption pathway for exposure assessment of *V. cholerae* in warm-water shrimp harvested and processed for international markets is shown in Fig. 7.1.

7.5 SOUS-VIDE

Sous-vide technology has considerable potential as a method for processing value-added seafood products. Raw or par-cooked food is sealed into a vacuumised, laminated plastic pouch or container, heat –treated by controlled cooking, rapidly chilled, and then reheated for service after a period of chilled storage (SVAC, 1991). An alternative to chilling sous-vide products post-cooking is freezing. Freezing has two advantages: (1) it minimises the risk of growth of *Cl. botulinum* spores, and (2) it extends product shelf life (Tansey *et al.*, 2003).

The minimum recommended thermal processing for sous-vide products is 90°C for 10 minutes ($P_{90} > 10$ minutes), or its time–temperature equivalent. Sous-vide/freezing technology has proved successful for cod and salmon portions as potential ready meal components (Rodgers, 2002).

Sous-vide technology poses a risk of botulism. Twenty-six catering and retail cook-chill meals were challenged with non-proteolytic *Cl. botulinum* (103 spores/g) and incubated for 10 days at 10°C (Rodgers, 2002). *Cl. botulinum* populations were enumerated on salicin tryptic soy agar and background microflora – on plate count agar. Botulinal toxin was detected using the enzyme-linked immunoassay. Only ten of the products supported the active growth of this pathogen. *Cl. botulinum* populations were static in another ten products which had a low pH except for two vegetable-based soups. In the remaining six products, *Cl. botulinum* populations reduced to undetectable levels. Although the predictive models described the general growth pattern of *Cl. botulinum* in the products supporting the active growth and the products with low pH values, they did not predict the spontaneous decline of this pathogen and the static populations in high pH vegetable soups.

Seven fish species (albacore tuna, cardinal fish, orange roughy, blue ling, redfish, roundnose grenadier and Greenland halibut) were cooked by the sous-vide process (Barriquand Steriflow retort; 20 minutes/90°C) in 12 savoury sauces (Fagan and Gormley, 2005). Sensory results showed that sous-vide-cooked albacore tuna, cardinal fish and blue ling were the most acceptable species and tikka, tomato-and-pesto, arrabbiata and hollandaise the preferred sauces. Greenland halibut and roundnose grenadier were too soft after sous-vide cooking. Freezing post-sous-vide cooking did not influence product quality and gave additional benefits over chilling of an extended shelf life and more flexibility in relation to product safety.

The pH of the sauces was in the range 3.96 (Cajun) to 5.42 (bearnaise) and mean pH values fell from 4.66 before sous-vide cooking to 4.38 after cooking. Sauce colour also became lighter during sous-vide cooking of fish portions, as indicated by HunterLab colour values. The results of the research were disseminated to seafood companies and scale-up trials are in still progress (Fagan and Gormley, 2005).

7.6 FILLETING OF WHITE FISH

Filleting involves a number of unit operations: pre-treatment, fish filleting, trimming of fillets, packing and storage. These processes generally take place within separate departments of the fish processing plant.

White fish species have a low-oil content and, unlike their oily fish counterparts, are generally gutted, cleaned and sometimes de-headed on board the fishing vessel. The fish are kept on ice in boxes before being delivered to the fish processing plant. On arrival at the plant, fish may be re-iced and placed in chilled storage until required for further processing.

Pre-treatment of the fish involves the removal of ice, washing, grading according to size and de-heading. Large fish may also scaled be before further processing.

The next step in the process is filleting, which is generally done by mechanical filleting machines. The filleting department is generally separated from the pre-treatment area by a wall, to prevent workers and goods passing from the non-sterile pre-treatment area to the sterile filleting area. The filleting machines comprise pairs of mechanically operated knives which cut the fillets from the backbone and remove the collarbone. Some fish fillets may also be skinned at this stage.

In the trimming department, pin bones are removed and operators inspect the fillets, removing defects and any parts that are of inferior quality. Off-cuts are collected and minced. Depending on the final product, the fillets may be cut into portions according to weight or divided into parts such as loin, tail and belly flap. As a final step before packaging, the fillets are inspected to ensure they meet product standard.

Fresh products are packaged in boxes with ice, the ice being separated from the products by a layer of

plastic. Frozen products can be packed in a number of ways. Fillets or pieces can be individually frozen and wrapped in plastic, but the most common method is for them to be packed as 6–11 kg blocks in waxed cartons. The blocks are typically frozen and then kept in cold storage. The flow diagram of filleting of white fish is given in Fig. 7.2.

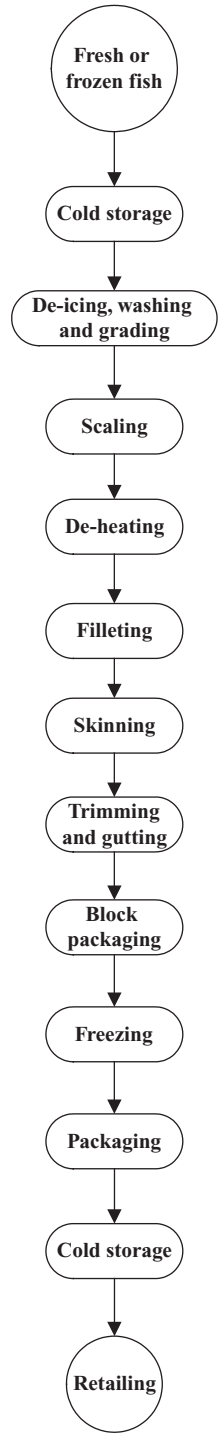

Fig. 7.2 Flow diagram for filleting of white and oily fish.

7.7 FISHERY CHAIN TRACEABILITY

Nowadays, fishery chain traceability is the most important tool for fish food safety and for consumers' protection (Borresen, 2004). Innovative and safe technologies are therefore necessary to assess species identification and authenticity testing. Among the variety of methods which are able to identify commercially imported fish and seafood species, molecular biotechnologies are becoming more widely utilised and are gaining increased attention (Borresen, 2004).

In the past, authenticity testing of fish products has been carried out using protein-based techniques; however, an innovative approach based on AFLP (amplified fragment length polymorphisms) markers has been proposed (Maldini *et al*., 2006). They evaluated the ability of AFLP to identify species and to confirm the authenticity of fish and seafood samples. The suitability of the AFLP fingerprinting technique was tested for classification, at the species level, of commercial products imported from various countries. The method was able to identify fish samples which were not classifiable on a morphological basis. The results obtained were organised with the aim of creating an AFLP database of reference species which would be useful in order to identify unknown commercial fish and seafood products. The analytical approach was presented in conjunction with the effectiveness of Genographer elaboration software in order to define diagnostic AFLP markers among different species.

Among the variety of PCR-based molecular markers, AFLPs have recently been used to investigate genomes of different complexities. A species database of fish, molluscs and crustaceans has been created with the aim of identifying the species of origin of seafood products by comparison with previously defined AFLP patterns. Different EcoRI and TaqI primer combinations were selected from 20 screened combinations in relation to the total number of detected fragments and polymorphic ones. The comparison of indicative markers between unknown frozen or fresh products and reference samples has enabled the accurate identification of 32 different species. The taxonomic characterisation has been performed either at the species or at the population level depending on

the number of available individuals. AFLP variation at the population level is particularly helpful for the stock traceability of domestic strains. Size homoplasy was also investigated in one species to assess the rate of non-homologous co-migrating fragments and to detect additional polymorphic markers to be used in stock identification. Results of band sharing index (BSI) and percentage of polymorphic fragments showed the wide applicability of AFLPs both for fish and seafood safety and authenticity testing in such fields as food traceability and restocking management.

In an attempt to address these complex issues, the European Commission funded a programme from 2000 to 2002 entitled 'Traceability of Fish Products', or TraceFish, a consortium made up of 24 companies and institutes including representatives from exporters, processors, importers and research institutes (http://www.Tracefish.org). The goal of TraceFish was to identify informational requirements for chain traceability and formulate voluntary industry standards for the electronic collection and dissemination of traceability data. This programme led to the development of standards for both captured fish and farmed fish chains as well as establishing standards for data transmission protocols. In their report (http://www.Tracefish.org) an attempt was made to identify all the variables that can be recorded at each step and divided these into three categories: information that 'shall be recorded' (required), information that 'should be recorded' (preferred), and information that 'may be recorded' (optional) (http://www.Tracefish.org).

These voluntary standards were first adopted by the European Committee for Standardisation (CEN, 2002), an organisation designed to promote voluntary technical harmonisation within Europe and these standards formed the basis for Europe's 2005 mandatory traceability requirements. Despite the development of these standards, a complete system for the collection and transmission of traceability data, including software to meet these standards, was not created by the TraceFish consortium. However, a traceability system was developed for the Danish fresh fish chain (Frederiksen and others 2002), which was in development before the TraceFish project. This research focused on all aspects of the fresh fish chain by using bar codes and serial shipping container codes to identify each resource unit and track each delivery. They showed that traceability could be achieved and recognised the fact that system costs for vessels and small firms need to be addressed and more user-friendly interfaces must be developed to promote efficiency.

Radio frequency identification (RFID) tags are becoming more widely accepted. RFID tags have the ability to hold large amounts of data, up to several megabytes, and can be custom-tailored to suit individual needs including time and temperature readings and tracking of product movement. These tags are of two types: passive and active.

Passive tags do not contain their own power source and are dependent on a signal from an RFID reader to start downloading their information.

Active tags come equipped with their own supply of power and actively send out radio signals that are received by RFID readers as they move into range, automatically downloading their information without the need to wait for a signal.

RFID tags are more expensive than UPC labels but have several additional features that make them appealing. They do not require manual scanning, and hundreds of RFID tags can be downloaded into a computer at one time. One potential liability is that humans cannot read RFID tags without the use of machines, making the reliability of an RFID system of utmost importance.

Implementing traceability systems will require improved vertical integration between entities and the development of standards for the collection and dissemination of traceability data. Fortunately, rapid advances in information technology have made it possible to implement traceability systems within the food industry. Thompson *et al*. (2005) explored the trends towards traceability in the US seafood industry.

Regulation (EC) No. 178/2002 (general principles and requirements of food law, establishment of the European Food Safety Authority and report of procedures in matters of food safety) and Regulation (EC) No. 853/2004 (specific hygiene rules for food of animal origin), which came into effect at the start of 2005, have put in place stringent guidelines requiring that all food manufactured and sold in the European Union, should be safe and fully traceable 'from farm to fork' and back again. Traceability was defined as the ability to identify a unique product, and the raw materials used in its production, and to follow the progress of that product right through the production and distribution process. Operators in the food sector are now required to have product withdrawal systems as well as records identifying the source of their raw material and the businesses they supply (http://www.idtechex.com/products/en/articles/00000178.asp). The Bioterrorism Act (2002) requires those who manufacture, process, pack, transport, distribute, receive, hold or import food in the USA to establish and maintain records to allow for the identification of the immediate previous sources and the immediate subsequent recipients of food. The requirements allow the FDA to locate food processors and others in the supply chain in the event of deliberate or accidental contamination of foods (http://www.foodproduction

daily-usa.com/news/ng.asp?id=68308-fda-traceability-bioterrorism).

These legal requirements do not require internal traceability, that is, a system which would allow linkages to be made between the sale of finished products and the source of materials used to produce them. Nevertheless, businesses may want to consider the benefits to be gained from such systems, specifically:

- improved consumer protection through better targeted, and more rapid recalls and/or withdrawals
- greater efficiency within businesses, with more information to assist in process control and management
- provision of reliable information to consumers to support authenticity claims about products
- deterrence of fraud and
- increased consumer confidence.

It is up to each business to decide whether to adopt internal traceability on the basis of costs and benefits.

Accurate and timely information and continued confidence in the information provided can be brought about by improved traceability records and regular testing of the robustness of their traceability and recall procedures. Some questions that food businesses should ask themselves are:

- How reliable are your traceability records?
- Has the robustness of traceability and recall procedures been tested?
- Have they been subjected to regular review?
- How far does traceability extend?
- What steps have been taken to verify the reliability of the traceability systems of the suppliers?
- In the event of an incident, is it possible to narrow down the problem to the affected batch or batches? (http://www.food.gov.uk/multimedia/pdfs/principles23mar07).

7.8 SHELLFISH

Molluscan shellfish include bivalves such as oysters, mussels, cockles, clams, and scallops, and gastropods with a characteristic whorled, snail-like shell. Crustaceans includes crabs, prawns, shrimps, lobsters and crayfish. The following are suggestions for the proper handling of shellfish according to HACCP (Mortimore and Wallace, 1994) and GMP (Gould, 1994):

- only live shellfish may be processed
- clams, mussels, and oysters that are used for canning shall not contain excessive green algae and shall be free from sand gravel, pearls, discolouration and shell pieces.

In general, shellfish are more susceptible than vertebrate fish to bacterial deterioration and penetration of pathogens, because of the large amounts of free amino acids their tissues contain (Cutting and Spencer, 1968). Spoilage due to autolysis is very rapid in shrimps and lobsters (Hobbs, 1982).

For oysters pH appears to be the most reliable chemical test for freshness. The pH falls progressively with spoilage, because of glycogen breakdown. The picric acid turbidity test and total volatile base test are promising indices of freshness of the American shrimp, *Penaeus*. The pH, total volatile bases and picric acid turbidity can be used for crab, total volatile bases for squid, and indole and pH for clams (Cutting and Spencer, 1968).

The heating of shrimp prepared for fish salad (60–80°C and only for a very short time) might not kill the cells of *L. monocytogenes*; more research is needed on this topic (Hartemink and Georgsson, 1991). Shellfish are often transported alive and without chilling. They can be contaminated with viruses from human sewage. Shellfish have been implicated in cases of food poisoning by enteroviruses and infectious hepatitis A (Tzouros and Arvanitoyannis, 2000). Especially for live storage, the combination of different lots of molluscan shellfish in the same display tank is not allowed (Price, 1995).

7.8.1 Oysters

The cultivation of oysters (*Crassostrea gigas*) is practised in very limited areas of the Italian coast and represents only a minor sector in the cultivation of bivalve molluscs, a well-established activity producing about 250,000 metric tonnes per year.

In spite of the limited incidence of oyster production in Italy, the peculiar organoleptic characteristics of their meat, increasingly appreciated by Italian consumers, and their high economic value make the sector of oyster cultivation a promising one.

Quality aspects of oysters (*Crassostrea gigas*) from a suspended culture in the lagoon of Venice (Valle Doga) were examined in different seasons over a 1-year period. Ecophysiological and commercial quality indicators (condition index, content of meat, shell and intervalvar fluid), nutritional quality parameters (proximate and mineral composition, glycogen content, fatty acid profile, cholesterol, plant sterols, fat-soluble vitamins content) and levels of organic pollutants (PCBs and organochlorine pesticides) were determined at different times of the year (Orban *et al.*, 2004). Seasonal variations were observed in the nutrient content, with particular regard to moisture (ranging from 866.8 g/kg in June to 938.8 g/kg in September), protein (23.9 g/kg in September to 76.6 g/kg in June), ash (22.5 g/kg

in February to 29.5 g/kg in July), lipid (3.0 g/kg in September to 8.8 g/kg in June) and glycogen (0.7 g/kg in September to 11.5 g/kg in February). In spite of this variability, the nutritional quality of the oysters was generally good, especially just before gamete release when the concentration of nutrients was at its maximum. Low levels of organochlorine chemicals were detected in the edible meat of oysters but, because only a limited number of samples were analysed, no general conclusion can be drawn on the safety of seafood from this area.

Two hazards might exist: *Haplosporidium nelsoni* and Herpes virus of oysters. Examples of risk management measures that the proponents propose to undertake:

For *H. nelsoni*:

- Health certificate to be provided
- PCR test to be undertaken from representative samples before departure and upon arrival
- Treatment of transport water

For herpes virus of oysters:

- Certification of the batch
- Quarantine
- PCR and in situ hybridisation tests on arrival
- Treatment of transport water (UV, chlorination, reverse osmosis)
- Imported animals not to be used as broodstock (Arthur *et al.*, 2004).

Shellfish (oysters and mussels) must enter the cold chain within 24 hours of harvest. A labelling amendment is recommended to verify this in terms of a harvest time being added to the label so that random checks could be made.

Transport of shellfish should be by a refrigerated vehicle (third party carriers) and should only be accepted if product is less than 10° at time of delivery. Refrigerated transport should not be used as the first point of cold chain management (FSA Australia-New Zealand, 2005). The potential food safety hazards along the molluscan shellfish supply chain are summarised in Table 7.2.

Processing of oysters before retail sale is usually minimal. When necessary, algae adhering to the shell are removed by tumbling, a process that can result in some damage to the oyster shells and potentially allow contamination of the meat. Oysters may be purified to some extent by relaying or depuration. These processes are reasonably efficient at reducing the load of enteric bacteria in oysters, but are significantly less effective at reducing the levels of viruses, endogenous marine pathogenic bacteria, chemicals and algal biotoxins.

The main processing of oysters involves shucking and packing in boxes for sale on the half shell or bottling in fresh water, depending on the grade. The shucking process does not kill pathogenic microorganisms or remove chemical contaminants, but introduces the potential for further contamination by enteric pathogens. In addition, the potential exists during shucking and transportation for temperature abuse, allowing multiplication of bacterial pathogens to levels that might pose a public health risk. Further handling in the distribution chain also carries with it the potential for contamination and temperature abuse (ANZFA, 2005).

V. vulnificus naturally inhabits warm estuarine environments and can infect humans via wound exposure or seafood consumption. These infections are rare and generally limited to individuals with preexisting chronic illnesses or the immunocompromised. However, *V. vulnificus* can invade through the intestinal barrier into the bloodstream causing primary septicaemia. As a result, it has the highest case/fatality rate (approximately 50%) among foodborne pathogens. *V. vulnificus* has been detected in a variety of seafood worldwide. Each year, 30–40 primary septicaemia cases are reported in the USA and nearly all are associated with consumption of raw oysters harvested from the Gulf Coast (WHO and FAO, 2005a).

A risk assessment for the pathogen–commodity pair of *V. vulnificus* in raw oysters was proposed by the European Community in the 33rd session of the Codex Committee on Food Hygiene (FAO/WHO, 2005). The report concluded that environmental conditions, especially high salinities, were not suitable for *V. vulnificus* survival. Like *V. parahaemolyticus*, *V. vulnificus* numbers at harvest are determined primarily by water, temperature and salinity. Other factors may also contribute to *V. vulnificus* numbers but only temperature and salinity have been quantified (Motes *et al.*, 1998; Tamplin, 1994).

The effect of salinity on predicted *V. vulnificus* numbers merits particular consideration. Effects of salinities on *V. vulnificus* may be stronger than on *V. parahaemolyticus* and lack of comprehensive season-specific and harvest-area-specific salinity data presents a potential data gap. There appears to be a threshold salinity (i.e. at or slightly above 30 ppt) at which point *V. vulnificus* levels drop substantially, regardless of temperature. This abrupt change in *V. vulnificus* levels relative to salinity and the observation of a large proportion of non-detectable levels at high salinities makes quantitative estimation of the joint effects of salinity and temperature problematic over the entire range of both moderate and high salinity (WHO and FAO, 2005a).

Table 7.2 Potential food safety hazards along the molluscan shellfish supply chain.

Supply chain sector	Source of hazards	Hazard examples
Pre-harvest	Bacterial, viral and chemical contamination by sewage	Enteric pathogens (*E. coli*, *S. aureus*, *Salmonella* spp., *Campylobacter* spp., *Shigella* spp., *Yersinia* spp., *L. monocytogenes*, hepatitis A virus, noroviruses) Agricultural chemical residues
	Exposure to environmental contaminants	Endogenous bacteria that are human pathogens (*A. hydrophila*, *V. parahaemolyticus, V. vulnificus*, *V. cholerae* O1, non-O1/non-O139 *V. cholerae* Chemical (algal biotoxins, mercury, cadmium, zinc)
Depuration and shucking	Contamination by shuckers	Microbiological pathogens (*E. coli*, *S. aureus*, *Salmonella* spp., *Campylobacter* spp., *Shigella* spp., *Yersinia* spp., *L. monocytogenes*, hepatitis A virus, noroviruses)
	Opportunity for outgrowth	Bacterial pathogens (*E. coli*, *S. aureus*, *Salmonella* spp., *Campylobacter* spp., *Shigella* spp., *Yersinia* spp., *L. monocytogenes*, *A. hydrophila*, *V. parahaemolyticus*, *V. vulnificus*, *V. cholerae* O1, non-O1/non-O139 *V. cholerae*)
	Reduction in level of hazards due to depuration	Reduced levels of some bacterial pathogens (*E. coli*, *S. aureus*, *Salmonella* spp., *Campylobacter* spp., *Shigella* spp., *Yersinia* spp., *L. monocytogenes*)
Transport, marketing, retailing and food service	Contamination by food handlers	Microbiological pathogens (*E. coli*, *S. aureus*, *Salmonella* spp., *Campylobacter* spp., *Shigella* spp., *Yersinia* spp., *L. monocytogenes*, hepatitis A virus, noroviruses)
	Opportunity for outgrowth	Bacterial pathogens (*E. coli*, *S. aureus*, *Salmonella* spp., *Campylobacter* spp., *Shigella* spp., *Yersinia* spp., *L. monocytogenes*, *A. hydrophila*, *V. parahaemolyticus*, *V. vulnificus*, *V. cholerae* O1, non-O1/non-O139 *V. cholerae*)

Adapted from ANZFA (2005).

When salinity was >30 ppt, 69% of US samples and 80% of Tokyo Bay samples, *V. vulnificus* numbers were less than the limit of detection (generally 0.3 MPN/g). Overall, conservative estimates of mean levels at >30 ppt were comparable with estimates of 8.5 and 9.3 *V. vulnificus*/g (Vv/g) based on the US and Japanese data, respectively (Oonaka *et al*., 2002).

Foodborne *V. vulnificus* infection is clearly associated with underlying medical conditions (Strom and Paranjpye, 2000). Liver disease is a prominent risk factor for *V. vulnificus* infection, including cirrhosis due to alcohol consumption. Additional risk factors include diabetes, gastrointestinal disorders (surgery, ulcers), haematological conditions, and immunodeficiency due to underlying conditions such as cancer and treatment of chronic conditions with immunosuppressive agents (e.g. arthritis). *V. vulnificus* may pose a small risk to otherwise 'healthy' individuals since a small fraction of cases (<5%) are reported to occur in individuals without any identifiable risk factor (Klontz, 1997). *V. vulnificus* causes a mild to severe gastrointestinal illness.

The numbers of *V. vulnificus* at consumption are influenced by ambient air temperatures at harvest, the time from harvest until the oysters are placed under refrigeration time until consumption. For oysters harvested during the summer and stored at ambient air temperature ranging from 24 to 33°C, a 1.3 $\log_{10}$ increase in *V. vulnificus* numbers was observed over 7.5 hours, with a plateau of approximately 2 $\log_{10}$ increase after a period of 14 hours (Cook, 1997).

Overall, the extent of growth occurring prior to the time of first refrigeration (i.e. time at which the oysters are first placed in refrigerated storage) is affected by:

- sampling air temperature corresponding to the water temperature at harvest
- sampling duration of harvest

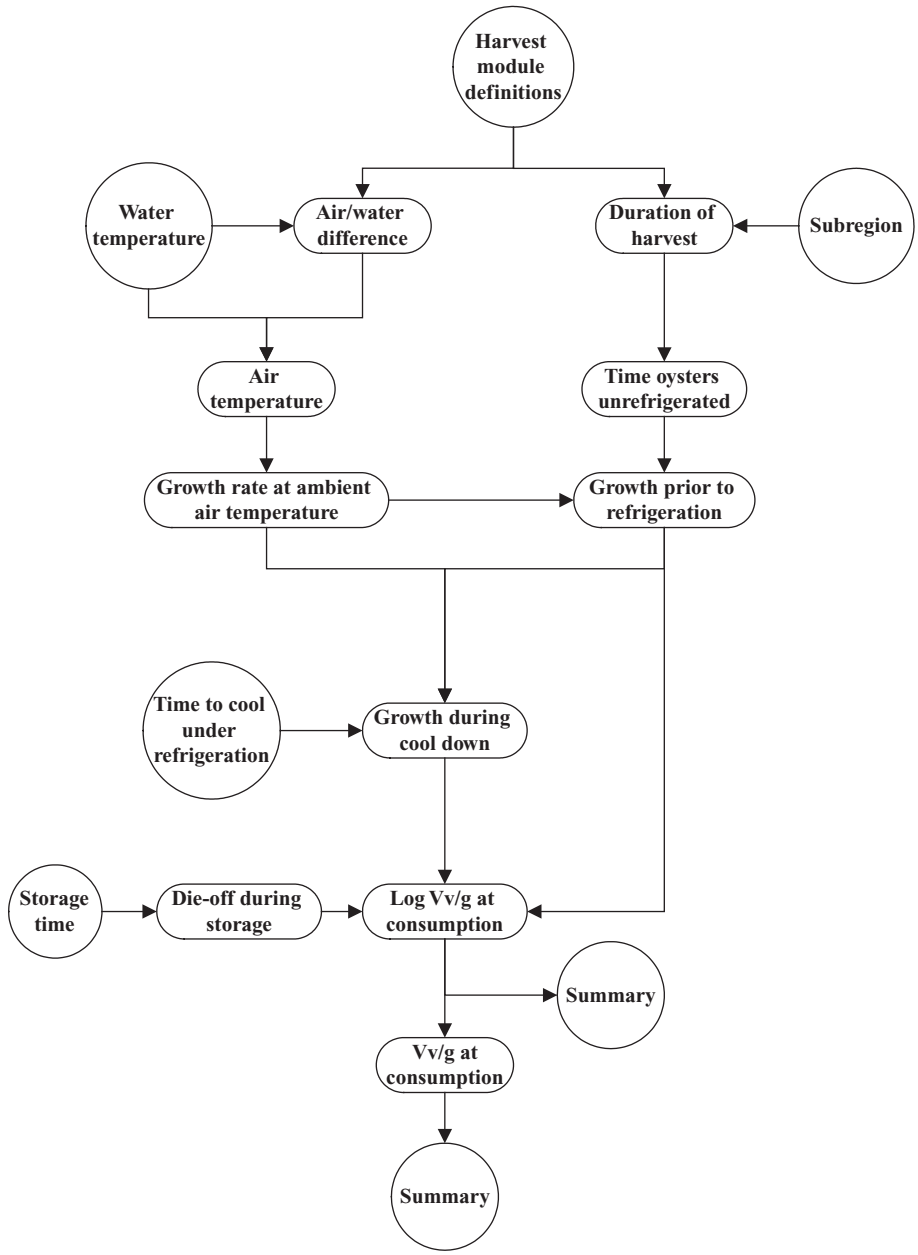

Fig. 7.3 Structure of simulation model of effect of post-harvest handling on Vibrio vulnificus/g (Vv/g) density.

- sampling the length of time unrefrigerated, given a particular duration of harvest and
- calculating the extent of growth expected considering both the given duration unrefrigerated and the air temperature. The structure of simulation model of effect of post-harvest handling on Vv/g density is given in Fig. 7.3.

7.9 CRUSTACEA

Crustacea specifically prawns and crayfish have been implicated in six outbreaks of foodborne illness in Australia in the period 1995–June 2002. The hazards involved have included hepatitis A virus, *S. typhi*, *S. typhimurium*, *V. cholerae* and *C. perfringens*. In the

case of the two outbreaks of perfringens food poisoning from consumption of curried prawns, the likely source of contamination is the spices used in the dish (CAC, 2003), as *C. perfringens* is not usually considered a seafood-associated pathogen.

Further evidence of a public health risk due to crustacea was found in the recently cooked prawns survey coordinated by ANZFA (1999). In this survey, 380 samples of chilled or frozen cooked prawn were tested for the standard plate count and *L. monocytogenes*. The retail temperature of the chilled prawns was also determined. The survey covered peeled and unpeeled, imported and domestic prawns.

The contamination rate of *L. monocytogenes* in cooked prawns was low (3%) and the levels of those detected were also low (<50 cfu/g). The standard plate counts ranged from negligible ($<10^3$ cfu/g) to high ($>10^7$ cfu/g), and the temperatures of cooked prawns varied from frozen to 12.8°C. However, there was no correlation between high standard plate counts and high temperatures. Results from the survey were used in the semi-qualitative risk assessment ANZFA conducted for '*Listeria monocytogenes* in cooked crustacea'.

Allergy to crustacea is quite common. People who are sensitive can react to different types of crustacean, e.g. shrimps, prawns and lobsters. Crustacea often cause severe reactions, and some people may respond to cooking vapours (FSA, 2005). Some people allergic to crustacea also react to molluscs (FSA, 2005).

For those sensitive to the cooking vapours, the amount of crustacean that can cause a reaction is likely to be very small. However, for oral sensitivity, eating as few as three or four medium-sized shrimps is sufficient to trigger a severe reaction in allergic individuals (FSA, 2005).

7.9.1 Cephalopods: Octopus vulgaris (common octopus)

Cephalopods are considered as the most active and specialised class of molluscs. They may have a chambered shell (e.g. Nautilus), an internal shell, as in squid (e.g. Loligo) and cuttlefish (e.g. Sepia) or no shell, as in octopods (e.g. Octopus, Eledone). They are almost all fast-swimming carnivores and live pelagically.

Only a few of the cephalopod species are commercially fished on a large scale (Kreuzer, 1984). Squid is by far the main cephalopod species, representing 73% of cephalopod world catches. Cuttlefish is the second and octopus the third, with 15% and 8.8%, respectively.

Cephalopods are a highly nutritious raw material. Due to lack of bones, the average edible part of the cephalopods is between 80 and 85% of the total body, which is higher than that of crustaceans (40–45%), teleosts (40–75%) and cartilaginous fish (25%) (Kreuzer, 1984). During the second half of the twentieth century, cephalopods were considered as less conventional resources, and consequently the catching of these species was recommended as a way of diversifying the fishing effort. Cephalopod landings have increased (FAO, 2001a,b; García *et al.*, 2006; Miliou *et al.*, 2005) and cephalopod fisheries are among the few fisheries with some potential for expansion. The range of value-added cephalopod products is very broad and includes chilled, frozen, dried and canned products, and recently as components of readymade meals; the largest share of sales is of chilled and frozen products.

Common octopus (*O. vulgaris*) is a cephalopod eaten mainly in Mediterranean, South American and Oriental countries and is typically marketed fresh, frozen and dried salted. Once caught, cephalopods undergo very rapid protein degradation due to endogenous and bacterial enzymes. Such high proteolytic activity produces an increase in levels of muscle-derived nitrogen, hence favouring proliferation of degenerative flora and rapid decomposition (Barbosa and Vaz-Pires, 2003).

Consequently, the shelf life of an octopus is extremely limited, typically 6–7 days after catch even at a low storage temperature of 2.5°C (Hurtado *et al.*, 1999) or eight days at 0°C (Barbosa and Vaz-Pires, 2003).

One biological peculiarity of cephalopod meat is the high solubility of its fibrillar proteins, causing loss in nutritive value by the leaching out of a considerable amount of protein when in contact with water. Washing, bleaching, brining, thawing in water, chilling, etc., need careful attention in the processing plants if nutritive quality and flavour are to be retained.

Cephalopod muscle, in general, gains in weight when in contact with cold water but loses nutrients quickly, much more readily than finfish muscle. The presence of chromatophores in the skin (pigment organs) also creates a series of processing problems, mainly in handling, freezing, cold storage, thawing and drying (Kreuzer, 1984). After death, the muscles attached to the chromatophores are no longer controlled, the chromatophores remain expanded and the muscles relax slowly, causing skin colour changes from dark to light within a few hours of death.

Methods recently recommended for quality evaluation include testing of sensory tables (Barbosa and Vaz-Pires, 2003), microbial counts and physical instruments (Vaz-Pires and Barbosa, 2003), chemical evaluations like agmatine (Ohashi *et al.*, 1991; Yamanaka

et al., 1987) and octopine (Respaldiza *et al*., 1997), and also microbial counts of psychrophilic bacteria like *Photobacterium phosphoreum* and *Pseudoalteromonas* (Paarup *et al*., 2002).

The potential for aquaculture of the cephalopod species *O. vulgaris* is evaluated by Vaz-Pires *et al*. (2004), taking into consideration biological and physiological characteristics, as well as some economic and marketing aspects, which may be relevant for the future development of octopus farming. *O. vulgaris*, a widespread, strictly marine species meets many of the requirements to be considered as a candidate for industrial culture: easy adaptation to captivity conditions, high growth rate, acceptance of low-value natural foods, high reproductive rate and high market price. The life cycle from eclosion of eggs to settlement or beginning of the benthonic adult phase is not commercially viable, but the published results from laboratory and pilot scales are promising. The determination of CCPs for octopus processing is given in Table 7.3. The ISO 22000 analysis worksheet for the determination of prerequisite programmes (PRPs) and the HACCP plan for octopus processing are summarised in Tables 7.4 and 7.5, respectively. The comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with PRP is shown in Table 7.6.

7.9.2 Reception of cephalopods

The processing facility should have a programme in place for inspecting cephalopods on catching or arrival at the factory. Only sound product should be accepted for processing.

Product specifications could include details as to the characteristics required for acceptable material:

- organoleptic characteristics such as appearance, odour, texture etc.
- chemical indicators of decomposition and/or contamination, e.g. TVBN, heavy metals (cadmium)
- microbiological criteria
- absence of parasites, e.g. *Anasakis*
- absence of foreign matter
- absence of lacerations, breakages and discolouration of the skin, or a yellowish tinge spreading from the liver and digestive organs inside the mantle, which are indicative of product deterioration.

7.9.3 Storage of cephalopods

Storage should be either chilled or frozen. Products in chilled storage should be held at 4°C. Modified atmosphere packaging (MAP) product should be held at 3°C or below. Seafood should be properly protected from filth and other contaminants through proper packaging and stored off the floor.

A continuous temperature recording chart for seafood storage coolers is recommended. Ready-to-eat items and molluscan shellfish should be kept separate from each other and other raw food products in chilled storage. Raw product should be stored on shelves below cooked product to avoid cross-contamination from drip.

Frozen storage is at −18°C or less. Regular temperature monitoring should be carried out. A recording thermometer is recommended.

7.9.4 Controlled thawing

The thawing parameters should be clearly defined and include time and temperature. This is important to prevent the development of pale pink discolouration. Critical limits for the thawing time and temperature of the product should be developed. Particular attention should be paid to the volume of product being thawed in order to control discolouration.

7.9.5 Splitting, gutting and washing

Gutting should remove all intestinal material and the cephalopod shell if present. Any by-product of this process which is intended for human consumption, e.g. tentacles and mantle, should be handled in a timely and hygienic manner.

Cephalopods should be washed in clean seawater or potable water immediately after gutting to remove any remaining material from the tube cavity and to reduce the level of micro-organisms present on the product.

An adequate supply of clean seawater or potable water should be available for the washing of whole cephalopods and cephalopod products (http://www.codexalimentarius.net/download/report/633/al28_18e.pdf).

7.9.6 Skinning and trimming

The method of skinning should not contaminate the product nor should it allow the growth of micro-organisms, e.g. enzymatic skinning or hot water techniques should have defined time/temperature parameters to prevent the growth of micro-organisms. An adequate supply of clean seawater or potable water should be available for the washing or product during and after skinning (http://www.fao.org/docrep/meeting/008/j1682e/j1682e04.htm).

7.9.7 Grading/packing

Packaging material should be clean, suitable for its intended purpose and manufactured from food-grade materials. Grading and packing operations should be

Table 7.3 Determination of critical control points for octopus processing.

A/A	Step	Hazard	Do control measure(s) exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of a hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable levels?	Will a subsequent step eliminate identified hazards or reduce likely occurrence to acceptable levels?	CCP
1	Receiving of raw materials-cephalopod reception	M	Yes	No	Yes	No	CCP1
		C	Yes	No	Yes	No	CCP1
		P	Yes	No	Yes	No	CCP1
2	Holding under chilling conditions	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P	Yes	No	No	—	CP
3	Controlled thawing with water	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P	Yes	No	No	—	CP
4	Freezing and frozen storage	M	Yes	No	Yes	No	CCP2
		C	Yes	No	No	—	CP
		P	Yes	No	Yes	No	CCP2
5	Washing with water	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P	Yes	No	No	—	CP
6	Cutting/splitting	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P	Yes	No	No	—	CP
7	Tentacles	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P				—	
8	Eyes, beak removed	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P	Yes	No	No	—	CP
9	Washing	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P	Yes	No	No	—	CP
10	Grading	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P	Yes	No	No	—	CP
11	Washing with water	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P	Yes	No	No	—	CP
12	Boiling and concentration	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P	Yes	No	No	—	CP
13	Packaging	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P	Yes	No	No	—	
14	Skimming	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P	Yes	No	No	—	CP
15	Trimming	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P	Yes	No	No	—	CP
16	Cutting	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P	Yes	No	No	—	CP

(*Continues*)

Table 7.3 (*Continued*)

A/A	Step	Hazard	Do control measure(s) exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of a hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable levels?	Will a subsequent step eliminate identified hazards or reduce likely occurrence to acceptable levels?	CCP
17	Filleting	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P	Yes	No	No	—	CP
18	Grading	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P	Yes	No	No	—	CP
19	Casing, labelling	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P	Yes	No	No	—	CP
20	Packaging	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P	Yes	No	No	—	CP
21	Storage in cans	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P	Yes	No	No	—	CP
22	Caging	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P	Yes	No	No	—	CP
23	Storage of raw materials	M	Yes	No	Yes	No	CCP3
		C	Yes	No	Yes	No	CCP3
		P	Yes	No	Yes	No	CCP3
24	Conveying	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P	Yes	No	No	—	CP
25	Washing/turning	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P	Yes	No	No	—	CP
26	Packing, filling, sealing	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P	Yes	No	No	—	CP
27	Butchering, packaging	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P	Yes	No	Yes	No	CCP4
28	Packing	M	Yes	No	Yes	No	CCP5
		C	Yes	No	Yes	No	CCP5
		P	Yes	No	Yes	No	CCP5
29	Brining	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P	Yes	No	No	—	CP
30	Finished product storage in cans	M	Yes	No	Yes	No	CCP6
		C	Yes	No	Yes	No	CCP6
		P	Yes	No	Yes	No	CCP6
31	Caging/distribution/ retail	M	Yes	No	No	—	CP
		C	Yes	No	No	—	CP
		P	Yes	No	No	—	CP

M, microbiological; C, chemical; P, physical.

Table 7.4 ISO 22000 analysis worksheet for the determination of prerequisite programmes for octopus processing.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Receiving of raw materials-cephalopod reception	Yes	Yes	No	No	No
Holding under chilling conditions	Yes	Yes	No	Yes	Yes
Controlled thawing with water	Yes	Yes	No	Yes	Yes
Freezing and frozen storage	Yes	Yes	No	No	No
Washing with water	Yes	Yes	No	Yes	Yes
Cutting/splitting	Yes	Yes	No	Yes	Yes
Tentacles	Yes	Yes	No	Yes	Yes
Eyes, beak removed	Yes	Yes	No	Yes	Yes
Washing	Yes	Yes	No	Yes	Yes
Grading	Yes	Yes	No	Yes	Yes
Washing with water	Yes	Yes	No	Yes	Yes
Boiling and concentration	Yes	Yes	No	Yes	Yes
Packaging	Yes	Yes	No	Yes	Yes
Skimming	Yes	Yes	No	Yes	Yes
Trimming	Yes	Yes	No	Yes	Yes
Cutting	Yes	Yes	No	Yes	Yes
Filleting	Yes	Yes	No	Yes	Yes
Grading	Yes	Yes	No	Yes	Yes
Casing, labelling	Yes	Yes	No	Yes	Yes
Packaging	Yes	Yes	No	Yes	Yes
Storage in cans	Yes	Yes	No	Yes	Yes
Caging	Yes	Yes	No	Yes	Yes
Storage of raw materials	Yes	Yes	No	No	No
Conveying	Yes	Yes	No	Yes	Yes
Washing/turning	Yes	Yes	No	Yes	Yes
Packing, filling, sealing	Yes	Yes	No	Yes	Yes
Butchering, packaging	Yes	Yes	No	No	No
Packing	Yes	Yes	No	No	No
Brining	Yes	Yes	No	Yes	Yes
Finished product storage in cans	Yes	Yes	No	No	No
Caging/distribution/retail	Yes	Yes	No	Yes	Yes

carried out with minimal delay to prevent deterioration of the cephalopod (http://nsgl.gso.uri.edu/flsgp/flsgph01002.pdf).

7.9.8 Freezing

Cephalopods should be frozen as rapidly as possible to prevent deterioration of the product and a resulting reduction in shelf life due to microbial growth and chemical reactions.

The time/temperature parameters developed should ensure rapid freezing of product and should take into consideration the type of freezing equipment, capacity, the size and shape of the product, and production volume. Production should be geared to the freezing capacity of the processing facility.

Table 7.5 HACCP plan for octopus processing.

Critical control point (CCP)	Significant hazard(s)	Critical limits for each preventive measure	Monitoring				Corrective action(s)	Records	Verification
			What	How	Frequency	Who			
Cephalopod reception	Pathogens from harvest area Natural toxins – CFP Scombrotoxin formation Environmental chemical contaminants and pesticides	No more than 2.5% decomposition (persistent and readily perceptible) in the incoming lot >0.3 ppm	Identify harvest area Harvest vessel records	Ask fishermen for the harvest location Sensory examination (118 cephalopod per lot; or all cephalopod in the lot if <118 cephalopod)	Every lot	Receiving employee Quality control staff Production supervisor	Reject lot Stop supplier until evidence is obtained that harvesting practices have changed	Receiving record	Review monitoring and corrective action records within 1 week of preparation
Receiving – labels	Pathogens from harvest area	All cephalopod labels must contain the raw consumption warning	Tags for finished product cephalopod	Visual	Three tags from each lot of tags	Receiving employee	Reject tags	Receiving record	Review monitoring and corrective action records within 1 week of preparation
Freezing	Parasites	Freezing at –35°C or below until solid and hold at –20°C or below for 24 hours	Temperature of blast freezer and storage freezer Length of time held frozen	Visual check of when first cephalopod is solid frozen and at end of freezing cycle Record temperatures	Continuous, with visual check at end of each freezing cycle When cephalopod is solid frozen and at end of each freezing cycle	Freezer operator Freezer operator	Adjust freezer Refreeze product Same	Recorder chart with notations for solid frozen and end of each cycle	Review monitoring, corrective action and verification records within 1 week of preparation Check the accuracy of the temperature recording devices daily
Raw material storage	Scombrotoxin formation	Product completely covered in ice throughout storage	Adequacy of ice surrounding product	Visual examination	Every lot at time of removal from raw material storage cooler and at least twice a day for lots not removed	Production supervisor	Add ice	Processing record	Review monitoring and corrective action records within 1 week of preparation

Butchering/ packaging	Scombrotoxin formation	Product is not exposed to temperatures above 4°C for more than 4 hours cumulatively if any of that time is above 21°C, or above 4°C for more than 8 hours as long as no portion of that time is above 21°C hours cumulatively	Time of product exposure to mollusk refrigerated conditions during butchering/ packaging	Visual tracking of time for marked product to move through butcher-ing/packaging	Every batch of mollusc marked when removed from raw material storage	Quality control supervisor	Reject lot	Processing record	
Finished product storage	Scombrotoxin formation	Product completely covered in ice throughout storage	Adequacy of ice surrounding product	Visual control	Every lot at time of removal from finished product storage cooler for shipment	Shipping supervisor	Add ice	Shipping record	Review monitoring and corrective action records within 1 week of preparation
Backing	Pathogen growth and toxin formation	No more than 2 hours cumulative time during backing, picking and packing	Time of product exposure to unrefrigerated conditions	Visual observation of marked containers	Start marked container every 2 hours during backing	Production supervisor	Immediately ice product or move to cooler	Production record	Review monitoring and corrective action records within 1 week of preparation
Backed cephalopod (mollusk) cooler	Pathogen growth and toxin formation	Cooler maintained at or below 4°C	Cooler temperature	Digital time/temperature data logger	Continuous with visual check once per day	Production supervisor	Move to alternate cooler and/or add ice	Data logger printout	Check accuracy of data logger against a standard thermometer once per day
Picking	Pathogen growth and toxin formation	No more than 2 hours cumulative time during backing, picking, and packing	Time of product exposure to unrefrigerated conditions	Visual observation of marked containers	Start marked container approximately every 2 hours during picking	Production supervisor	Immediately ice product or move to cooler	Production record	Review monitoring and corrective action records within 1 week of preparation

(*Continues*)

Table 7.5 (Continued)

Critical control point (CCP)	Significant hazard(s)	Critical limits for each preventive measure	Monitoring				Corrective action(s)	Records	Verification
			What	How	Frequency	Who			
Finished product cooler	Pathogen growth and toxin formation	Cooler maintained at or below 4°C	Cooler temperature	Digital time/temperature data logger	Continuous with visual check once per day	Production employee	Move to alternate cooler and/or add ice	Data logger printout	Check accuracy of data logger against a standard thermometer once per day
Packing	Pathogen growth and toxin formation	No more than 3½ hours cumulative time during packing	Time of product exposure to unrefrigerated conditions	Visual observation of time that the last container of mollusc from the batch is packed on ice	Every batch	Packing room employee	Hold and evaluate based on total time/temperature exposure	Packing record	Study showing temperature profile of product during processing
Finished product storage	Pathogen growth and toxin formation	Finished product containers completely surrounded with ice	Adequacy of ice	Visual observation	Each case immediately before shipping	Shipping employee	Re-ice Hold and evaluate based on total time/temperature exposure	Shipping record	Review monitoring and corrective action records within 1 week of preparation
Brining	*Cl. botulinum* toxin formation in finished product	Minimum brining time 6 hours Minimum salt concentration of brine at start of brining 60% salimeter Minimum ratio of brine mollusc: 2:1 (note: To produce minimum water phase salt level in the loin muscle of 3.5%)	Length of brining process Salt concentration of brine Weight of brine (as determined by volume) Weight of molluscs Molluscs thickness	Visual Salinometer Visual to mark on tank Scale Calliper	Start and end of brining process Start of brining process Start of brining process Each batch Each batch (ten molluscs)	Brine room employee	Extend brining process Add salt Add brine Remove some molluscs and reweigh Hold and evaluate based on finished product water phase salt analysis	Production record	Documentation of brining/drying process establishment Review monitoring, corrective action, and verification records within 1 week of preparation Monthly calibration of scale Quarterly water phase salt analysis

Finished product storage	*Cl. botulinum* toxin formation during finished product storage	Maximum cooler temperature 4°C (based on growth of vegetative pathogens)	Cooler air temperature	Digital data logger	Continuous, with visual once per day	Production employee	Adjust or repair cooler, and Hold and evaluate based on time/temperature of exposure	Data logger printout	Review monitoring, corrective action and verification records within 1 week of preparation Daily check of data logger accuracy
Drying (forced convection oven)	Pathogen growth and toxin formation	Maximum product thickness 1/4 inch Minimum drying time 5 hours Minimum oven temperature 60°C To achieve a final water activity of 0.85 or less	Product thickness Drying time Oven air input temperature	Preset slicer to just less than 1/4 inch Digital time/temperature data logger	Once per day before operations Continuous, with visual check each batch	Slicer operator Oven operator	Readjust slicer Continue drying Extend drying process Segregate product and hold for evaluation Evaluate by performing water activity analysis on finished product. Re-dry if more than 0.85	Processing log Data logger printout	Documentation of drying process establishment Review monitoring, verification and corrective action records within 1 week of preparation Check the accuracy of the data logger daily Analyse finished product sample once every 3 months for water activity
Labelling receipt	Sulfiting agents	All finished product labels must contain sulfiting agent declaration	Finished product labels for presence of sulfiting agent declaration	Visual	One label from each case of labels at receipt	Receiving employee	Segregate and return any labels that do not contain the sulfiting agent declaration	Label receiving record	Review monitoring and correction action records within 1 week of preparation
Molluscs receiving	Sulfiting agents	Incoming lots of mollusc must be accompanied by a supplier's certificate that sulfiting agents were not used on the lot	Supplier's lot-by-lot certificate that no sulfiting agents were used on the lot	Visual	Every lot of incoming mollusc	Receiving employee	Reject any incoming lot of molluscs that is not accompanied by a supplier's certificate	Copies of supplier's guarantees	Test one lot per quarter for sulfiting agent residue, and test one lot from each new supplier of molluscs for sulfiting agent residue Review monitoring, correction action and verification records within 1 week of preparation

(*Continues*)

Table 7.5 (Continued)

Critical control point (CCP)	Significant hazard(s)	Critical limits for each preventive measure	Monitoring				Corrective action(s)	Records	Verification
			What	How	Frequency	Who			
Metal detection	Metal inclusion	No detectable metal fragments in finished product	Presence of detectable metal fragments in finished product	Metal detector	Every finished product package, with operation check before start-up	Production employee	Destroy any product rejected by metal detector Identify source of metal founding product and fix damaged equipment If product is processed without metal detection hold for metal detection	Metal detector operation log	Test metal detector with three test units before production each day, and recalibrate if needed Review monitoring, corrective action and verification records within 1 week of preparation
X-ray equipment	Glass inclusion	No detectable glass fragments in finished product	Presence of detectable glass fragments in finished products	X-ray device	Every finished product package, with operation check before start-up	Production employee	Destroy any product rejected by X-ray equipment Stop operations and identify source of glass found in product and fix damaged equipment If product is processed without X-ray equipment, hold for detection by off-line X-ray equipment	X-ray operation log	Test X-ray device before production each day, and recalibrate if needed Review monitoring, corrective action and verification records within 1 week of preparation

Adapted from Miliou *et al.* (2005) and Vaz-Pires *et al.* (2004).

Table 7.6 Comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with PRP for octopus processing.

Process step	HACCP CCPs	Prerequisite programme according to ISO 22000?	ISO 22000 CCPs
Receiving of raw materials – cephalopod reception	1	No	1
Holding under chilling conditions		Yes	
Controlled thawing with water		Yes	
Freezing and frozen storage	2	No	2
Washing with water		Yes	
Cutting/splitting		Yes	
Tentacles		Yes	
Eyes, beak removed		Yes	
Washing		Yes	
Grading		Yes	
Washing with water		Yes	
Boiling and concentration		Yes	
Packaging		Yes	
Skimming		Yes	
Trimming		Yes	
Cutting		Yes	
Filleting		Yes	
Grading		Yes	
Casing, labelling		Yes	
Packaging		Yes	
Storage in cans		Yes	
Caging		Yes	
Storage of raw materials	3	No	
Conveying		Yes	
Washing/turning		Yes	
Packing, filling, sealing		Yes	
Butchering, packaging	4	No	
Packing	5	No	3
Brining		Yes	
Finished product storage in cans	6	No	4
Caging/distribution/retail		Yes	

The product temperature should be monitored regularly to ensure the completeness of the freezing operation as it relates to the core temperature. Adequate records should be kept for all freezing and frozen storage operations (http://www.fao.org/docrep/meeting/008/j1682e/j1682e04.htm).

7.9.9 Packaging, labelling and ingredients – reception and storage

Consideration should be given to the potential hazards and defects associated with packaging, labelling and ingredients. Care should be taken to ensure that handling, labelling and product packaging are conducted in accordance to the guidelines of PRPs.

Care should be taken to ensure that product is not subjected to temperature abuse during packaging and handling.

Care should be taken to avoid cross-contamination of ready-to-eat and raw shellfish, shellfish and their products at the work areas or by utensils or personnel (http://www.codexalimentarius.net/download/report/633/al28_18e.pdf).

7.10 SALMON

The salmon in the Atlantic Ocean (*Salmo salar*) began to be cultivated in the internal waters of England in the nineteenth century in order to supplement the wild population. The aquaculture breeding in oceanic cages was used initially in Norway in the 1960s with a view to achieving a growth corresponding size of wild-caught fish. The aquaculture success in Norway encouraged the development of large-scale commercial salmon aquaculture in Scotland, Ireland, Canada,

the North-East Coast of the USA and recently in Chile and Australia (Tasmania). Apart from these countries, New Zealand, France and Spain have also developed salmon production on a smaller scale.

Atlantic salmon (*Salmo salar*) is important among the various species cultured worldwide and its contribution to the total aquaculture production in 1999 was 2.39% (FAO, 2001a,b). Norway, Chile and the UK (Scotland) are the three major producers of farmed Atlantic salmon. Scotland's production of Atlantic salmon was estimated around 120,000 tonnes and 158,000 tonnes in 2000 and 2001, respectively (Anonymous, 2001). Salmon farming is an important enterprise in Scotland and the product has achieved a superior quality reputation over its Scandinavian counterparts, which is reflected in a premium price.

While world production of Atlantic salmon has increased, problems related to quality still persist. The temperature in the cold-smoking process never exceeds 28–32°C, which limits inactivation of enzymes in salmon tissue (Hansen *et al*., 1996). In the German markets serious problems with sensory acceptability at the end of the declared minimal shelf life has arisen as a result of tissue softening and texture changes which were reported to occur before off-flavours and off-odours were produced (Hildebrandt and Erol, 1988). Most of the deteriorative changes that reduce shelf life of fishery products are due to enzymic activities. The presence of primary foodborne pathogens like *L. monocytogenes* and *Cl. botulinum* type E are also of major concern in cold-smoked products (Ward, 2001).

Positive conclusions have been established from various studies conducted on seafoods using high-pressure processing that this technology could be applied to seafoods to extend the shelf life. It achieves this by controlling or inactivating seafood-related spoilage enzymes, modifying texture, and stabilising colour and lipid oxidation (Chevalier *et al*., 2001; Master *et al*., 2000).

The effects of smoking, drying, enzymatic spoilage, feed usage, textural and biochemical changes during frozen storage of cold-smoked salmon are described by Lakshmanan *et al*. (2003). Important pathogens associated with cold-smoked salmon, such as *L. monocytogenes* and other spoilage organisms, are also described and potential areas for further research are identified.

The major steps in the preparation of smoked fish are salting (bath or injection of liquid brine or dry salt mixture), cold smoking, cooling, packaging (air/vacuum or modified) and storage. Smoking, one of the oldest preservation methods, combines the effects of salting, drying, heating and smoking. Smoking of fish is either cold (32°C) or hot (70–80°C) typically. Cold smoking does not cook the flesh, coagulate the proteins, inactivate food spoilage enzymes or eliminate the food pathogens and hence refrigerated storage is necessary until consumption. Gaping is a serious problem associated with cold-smoked salmon. It is characterised by separation of myocommata that makes it difficult to process and sell high-value fillets of cold-smoked salmon (Skjervold *et al*., 2001). The common factors associated with gaping are low pH, smoking process, and prolonged storage before freezing, mechanical damage during handling and lack of proper chilling.

In general, the countries producing salmon are situated between the geographical latitudes 40–70° in the northern hemisphere and 40–50° in the southern hemisphere.

The early Norwegian success in salmon farming was the result of having well-protected sea areas with perfect hydrographic conditions (constant temperature and salinity), backed by considerable financial support from the Norwegian government (FAO, 2001a,b).

The fish reception is the first stage in the flow diagram of salmon alteration. The fish are collected alive from the aquaculture farms, which are located in specially chosen areas (Pedrosa-Menabrito and Regenstein, 1990) and are killed by freezing (ice overlay) (Lupin 1995). The fish are carried in boxes made of heat-insulating material, which are covered with ice. During their transfer, the temperature must be kept at low levels (0–4°C). In particular, the main events that occur after the death of the fish are muscular inflexibility, auto-oxidation and bacterial denaturation. Consequently, the fish cooling must start just after capture, so that its temperature should be reduced to 3°C or less in about 1 hour (ICMSF, 1988). Great attention should be given in cases where the aquaculture farms are far away from the processing (smoking) plants. In these cases, the transportation should take place in vans at freezing temperatures (<−18°C). The stage of fish collection is a CCP, since the fish might be polluted by biological and chemical factors, which depend on the area where the fattening farm is installed as well as on the prevalent conditions (Pedrosa-Menabrito and Regenstein, 1990).

The next stage is that of weighing. This stage determines the amounts of fish to be altered and helps to classify the fish, in order to create a classification of the product with regard to the weight (CFIA, 1997a). Classification is followed by evisceration. The processing industry should comply with hygiene principles as well as GMP practices in order to avoid undesirable effects on the quality of the altered product. Therefore, the workers must wear gloves and a skull-cap as well as a white pinafore down to the knees and white boots. The evisceration of large fish occurs both on

the fishing vessels and in terrestrial processing units. The complete disinfection of machines is very important because the residues of the process (flesh, blood etc.) are an excellent substrate for pathogenic micro-organisms (Olsen, 1995).

Following the evisceration stage the production line is divided into three sub-parts: (i) the part of fresh salmon, (ii) the part of frozen salmon and (iii) the part of fillet processing.

On the fresh salmon production line the next stage is that of blood removal. This stage is a CCP because the water used must be potable, well filtered so as to remove harmful substances and micro-organisms and compatible with the requirements of the 80/778/EC instruction. After blood removal the fish are classified with regard to the size and quality. Thereafter fish are placed in heat-insulating packages, which are covered with a transparent membrane suitable for foods. The packing, cooling/conservation, which is effected at 4°C, follows. This stage is a CCP, because the fish will be spoiled if the temperature is higher (Garthwaite, 1992). For this reason the checking of the temperature control of cooling installations is necessary at regular periods. The fish are then placed in boxes which are marked on their external side (CFIA, 1997b). At this stage the personnel must abide by the hygiene rules, so as to avoid contamination of the packaged fish. Moreover, labelling must be definitive and correct. The boxes are placed in the freezer (−18°C) till their transport to the market for sale. It is important for the freezing temperature to remain constant during transport, which should be carried out with transportation vehicles operating at −18°C.

In the department preparing salmon for the freezer evisceration is followed by chilling in ice which must be mechanically produced (Lupin 1995). Thus, the temperature of the fish's body should be kept low in order to avoid contamination and protein denaturation. Afterwards, the fish are washed with potable water and then waste water is well filtered so as to remove harmful substances. Then, the fish are hung to drain away liquids during which period the fish must be kept at a temperature of 4°C. Following this, the fish have ice applied to their surface, i.e. a small layer of ice is added to protect them from possible contamination. They are then placed in cases and labelled (CFIA, 1997b). During the encasement, the above-mentioned hygiene measures are applied. Finally, the cases are placed under freezing conditions at −20°C or even lower temperatures (Hsing-Chen, 1995) ready for transport, in refrigerated vans, to the market for sale.

Fillet production also begins after evisceration and washing with water to ensure complete blood removal. The same measures as described for the chilled and frozen fish are applied in order to avoid contamination and product denaturation. Sorting and placement of fish on ice in order to be maintained at low temperature are also similar. The next step is the head removal, which is considered to be a critical point (CCP), since the risk of entrance of foreign matter (hair) into the fish exists at this point in the process, which is undesirable. Following head removal, washing is carried out to remove any remaining offal. Filleting then follows during which a transverse section is carried out along the vertebral column on both sides of each fish. A good filleting process removes almost all the initial microbial load of the fish, hence it is easy to produce fillets with no microbes and with a satisfactory shelf life even from a fish with a high microbial load. Despite that, this stage is a CCP because fillets might be contaminated by both pathogenic micro-organisms and physical contaminants. The possibility of the appearance of skin, bones and membranes in fillets also exists. Regular preventative maintenance in conjunction with continuous monitoring of the production line and direct corrective actions in the case of deviations should prevent such phenomena. Product lots with defects get exemptions and may be processed for a second time (Huss, 1995b). To reduce these hazards the processing units use good hygiene and control practices. Following removal of the skin of the fillets they may be immersed in a dressing sauce depending on the intended market/use. This is considered a CCP because the sauce could carry a microbial load or pathogenic micro-organisms such as *E. coli*.

Removal of any excess sauce and examination for any macroscopic defects follows immediately. The whole process of fillet preparation should not last for more than an hour so as to reduce the hazard of spoilage of the fillets. The next stage is that of cooling and the process of addition of ice. Fillets are then placed in packages made from heat-insulating material covered by a transparent membrane suitable for food. Packaging should be carried out under cooling conditions to avoid possible growth of micro-organisms (Garthwaite, 1992). Fresh and frozen salmon fillets should be packaged in cases which should be appropriately labelled. Labelling should be thorough and in accordance with all current regulations mentioning all the substances added to the food. In the case of a deviation in labelling the machines should be stopped, the right labels should be inserted and the defective load should be isolated and relabelled (CFIA, 1997b). Finally, cases are frozen until sold. The flow diagram of salmon processing is shown in Fig. 7.4. The salmon specifications are described in Table 7.7. The questions used to derive a CCP for salmon processing according to HACCP analysis are given in Table 7.8. The

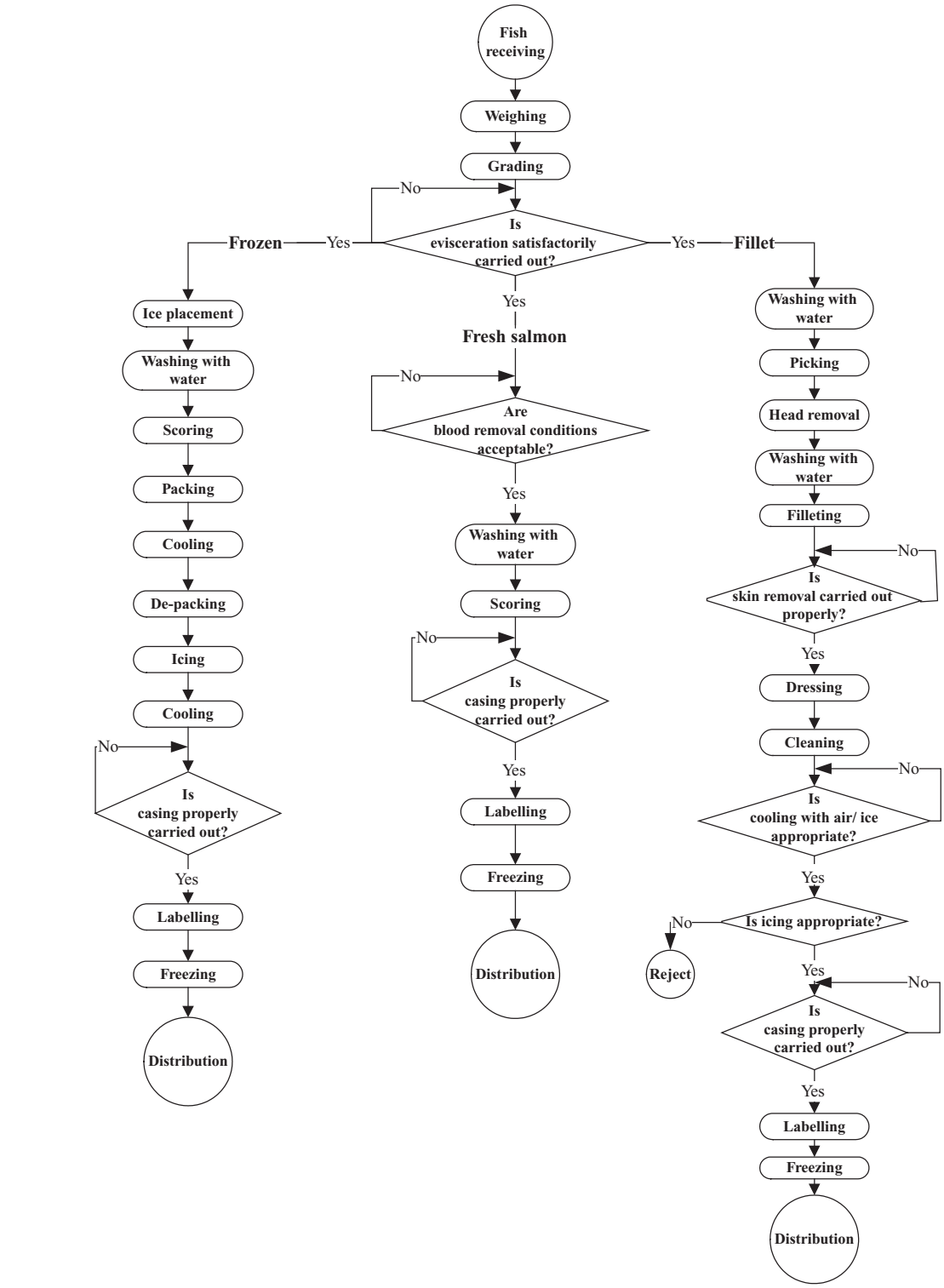

Fig. 7.4 Flow diagram of salmon processing.

Table 7.7 Salmon specifications.

Firm name	Hot Smoked Fish Company, Inc.
Firm address	USA
Product description	Refrigerated, vacuum-packaged, cooked ready-to-eat smoked fish (no mercury-containing species used
Storage and distribution	Stored and transported under refrigeration
Intended use and consumer	Ready to eat by general public without further cooking

CCPs, hazards, critical limits, corrective actions and records and the ISO 22000 analysis worksheet for determination of some PRPs for salmon processing are summarised in Tables 7.9 and 7.10, respectively. The comparative presentation of CCPs of HACCP and ISO 22000 is given in Table 7.11.

7.11 CANNED FISH PRODUCTS

Based on the available consumption data, canned fish products are considered as a food group that is regularly eaten by a significant proportion of the population. Canning is designed to reduce levels of heat-resistant bacterial spores (especially those of *Cl. botulinum*) to negligible levels, providing that GMPs and approved thermal processes are applied. This is a well-established practice for the production of shelf-stable products. The likelihood of adverse health effects due to bacterial contaminants is therefore negligible in a properly controlled canning process. Viral pathogens and helminthic parasites will also be destroyed (ANZFA, 2005).

The concentration of inorganic arsenic is not affected by the canning process, and its concentration in the final product will reflect the concentration in the raw materials. As described for chilled/frozen whole fish and fillets, the likelihood of adverse health effects due to inorganic arsenic is considered low.

Concentrations of MeHg are unaffected by canning, although for tuna, different species are used for canning, so canned tuna typically has lower levels of mercury than tuna sold fresh. Other fish species associated with high mercury levels (e.g. shark, orange roughy) are not normally canned. Concentrations in the final product will reflect concentrations in the raw materials.

The enterotoxin produced by *S. aureus* is extremely heat stable, and may survive the heat processes used to sterilise low-acid canned foods (ICMSF, 1996). However, production of significant amounts of toxin needs high cell densities (that usually only occur in the late logarithmic or lag phases of growth), and would need significant contamination and time–temperature abuse of the fish prior to canning.

Time–temperature abuse of fish intended for canning will potentially allow formation of histamine. Histamine (and other biogenic amines) is not destroyed in the canning process. Data from testing of samples at retail indicate only a low prevalence of histamine in canned fish (ANZFA, 2005).

There are three essential maxims of cannery safety:

(a) Container seal integrity
(b) Adequate thermal process lethality
(c) Scrupulous post-process hygiene.

In the fish itself, heat transfer is predominantly conductive and it takes a great deal of time. End-over-end rotation while heating is more efficient in this respect than the axial rotation. Severe heat processing should be avoided so that quality does not deteriorate (Barnes, 1980) and thermal processing should be based on 12-D process in order to eliminate the danger of *Cl. botulinum* (Horner, 1992b).

Time–temperature function integrators convert the temperature history of the canned fishery to an equivalent time at some reference temperature where the product's shelf life is known (0°C for fish) and gives a continuous display of elapsed storage life at this reference temperature. Combined relative humidity and temperature loggers are also available, though humidity meters are not so functional at the water activity of most foods (McMeekin *et al*., 1992).

The principles of effective canning can be summarised as follows:

- The use of hermetically sealed containers, impermeable to liquids, gases and micro-organisms.
- Applying a heat process sufficient enough to inactivate toxins, enzymes, and micro-organisms that can act extensively at temperate storage and distribution temperatures.

Outbreaks of botulism and histamine poisoning and a few cases of *Staphylococcus* enterotoxin poisoning have been reported in canned fish. For low-acid canned foods (pH > 4.6) such as canned seafoods, the major organism of concern is the pathogenic spore-forming *Cl. botulinum*. The target of thermal processing is the decrease of the population *Cl. botulinum* spores to 10^{-12} of its initial population provided the raw material was not highly contaminated.

The sterilisation or pasteurisation heat treatment used in canned food production is referred to as 'the

Table 7.8 Questions used to determine CCPs for salmon processing according to HACCP analysis.

Processing step	Determination of hazards	Do preventative control measures exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable level(s)?	Will a subsequent step eliminate identified hazard(s) or reduce likely occurrence to acceptable levels?	Is this step a critical control point?
Receipt of fish	Biological: Pathogenic micro-organisms, parasites	Yes	No	Yes	No	CCP1
	Chemical: Heavy metals, pesticide residues	Yes	No	Yes	No	
	Physical: Extrinsic deformations, bruises.	Yes	No	Yes	No	
Weighing	Biological: No identified hazard	No	No	No	Yes	
	Chemical: No identified hazard	No	No	No	Yes	
	Physical: No identified hazard	No	No	No	Yes	
Grading	Biological: No identified hazard	No	No	No	Yes	
	Chemical: No identified hazard	No	No	No	Yes	
	Physical: No identified hazard	No	No	No	Yes	
Evisceration	Biological: Microbial infection, parasites	Yes	No	Yes	No	CCP2
	Chemical: Chemical contamination	Yes	No	Yes	Yes	
	Physical: Foreign matter	Yes	No	Yes	Yes	
Blood removal	Biological: Water infected with pathogenic micro-organisms	Yes	Yes	—	—	CCP3
	Chemical: Infectious agents in water	Yes	Yes	—	—	
	Physical: No identified hazards	Yes	Yes	—	—	
Washing	Biological: Microbial contamination	Yes	Yes	—	—	CCP4
	Chemical: Heavy metals	Yes	Yes	—	—	
	Physical: Non-potable water	Yes	Yes	—	—	

Table 7.8 (Continued)

Processing step	Determination of hazards	Do preventative control measures exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable level(s)?	Will a subsequent step eliminate identified hazard(s) or reduce likely occurrence to acceptable levels?	Is this step a critical control point?
Sorting	Biological: No identified	Yes	Yes	—	—	
	Chemical: No identified hazard	Yes	Yes	—	—	
	Physical: Foreign matter	Yes	Yes	—	—	
Head removal	Biological: Microbial contamination, parasites	Yes	No	No	—	
	Chemical: Chemical contamination	Yes	No	No	—	
	Physical: No identified hazard	Yes	No	No	Yes	
Fillet making	Biological: Microbial contamination, parasites	Yes	No	Yes	No	CCP5
	Chemical: Chemical contamination	Yes	No	No	No	
	Physical: No identified hazard	Yes	No	No	No	
Skin removal	Biological: Microbial contamination, parasites	Yes	No	No	Yes	
	Chemical: Chemical contamination	Yes	No	No	Yes	
	Physical: Foreign matter	Yes	No	No	Yes	
Dressing	Biological: Growth of pathogenic micro-organisms	No	No	Yes	Yes	
	Chemical: Industrial chemical compounds	No	No	Yes	Yes	
	Physical: None	No	No	No	Yes	
Hanging	Biological: No identified hazards	No	No	No	Yes	
	Chemical: No identified hazard	No	No	No	Yes	
	Physical: No identified hazard	No	No	No	Yes	

(*Continues*)

Table 7.8 (Continued)

Processing step	Determination of hazards	Do preventative control measures exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable level(s)?	Will a subsequent step eliminate identified hazard(s) or reduce likely occurrence to acceptable levels?	Is this step a critical control point?
Icing	Biological: Microbial infection	No	No	No	Yes	
	Chemical: Industrial chemical compounds	No	No	No	Yes	
	Physical: Foreign matter	No	No	No	Yes	
Sorting	Biological: No identified hazard	Yes	Yes	No	No	
	Chemical: No identified hazard	Yes	Yes	No	No	
	Physical: Foreign matter	Yes	Yes	No	No	
Cooling with air or ice	Biological: Growth of micro-organisms, parasites	Yes	Yes	—	—	CCP6
	Chemical: Rare	—	—	—	—	
	Physical: Foreign matter	Yes	No	No	—	
Casing	Biological: Growth of pathogenic micro-organisms	Yes	No	Yes	No	CCP7
	Chemical: Chemical contamination	Yes	No	Yes	No	
	Physical: Foreign matter	Yes	No	Yes	No	
Labelling	Biological: No identified hazard	No	No	Yes	No	
	Chemical: No identified hazard	No	No	Yes	No	
	Physical: Foreign matter	No	No	Yes	No	
Freezing	Biological: Microbial growth, parasites	Yes	No	Yes	No	
	Chemical: Rare	Yes	No	Yes	No	
	Physical: Deterioration, quality loss due to slow freezing	Yes	No	Yes	No	
Distribution	Biological: Microbial growth and contamination	Yes	No	Yes	No	CCP8
	Chemical: Chemical contamination	Yes	No	Yes	No	
	Physical: Product destruction	Yes	No	Yes	No	

Table 7.9 Critical control points, hazards, critical limits, corrective actions and records for salmon processing.

Critical control point (CCP)	Significant hazards	Critical limits for each measure	Control				Corrective action	Records	Verification
			What	How	Frequency	Who			
Whole salmon receiving	Pathogenic micro-organisms from breeding unit Biotoxins Histamine formation Environmental infectious agents and pesticides Heavy metals	Determined by national regulations <100 ppm histamine >2 mg per 100 g body weight	Determination of the cultivation area	Chemical and microbiological analysis Macroscopic control Questionnaire for the location of the breeding unit	For every supplier	Production supervisor Quality control staff.	Stop fishing authorised by control agencies Remove fish Stop working with these suppliers	Receiving records	Review, control and record correction 1 week following incident occurrence
Evisceration	Biological danger: Pathogenic micro-organisms	No presence Process should not last more than 1 hour. Possible suspicion for contamination should place the product on hold	Determination of the possible consequences in fish from wrong application of the technique	Macroscopic control Temperature recording meters Sampling for microbiological control	For every lot produced in 1 hour	Production staff Production supervisor	Good hygiene practice, tools disinfection following evisceration	Processing	Review of the evisceration technique and macroscopic control of fish to detect any contamination
Blood removal	Biological hazard: Pathogenic micro-organisms Running water for washing	No presence Process should not last more than 1 hour Possible suspicion for contamination should place the product on hold	Determination of the possible consequences in fish from wrong application of the technique	Macroscopic control Temperature recording meters Sampling for microbiological control	For every lot produced in 1 hour	Production staff Production supervisor	Good hygiene practice, good filtration of washing water	Processing	Review of the technique and macroscopic control of fish to detect any contamination

(*Continues*)

Table 7.9 (*Continued*)

Critical control point (CCP)	Significant hazards	Critical limits for each measure	Control				Corrective action	Records	Verification
			What	How	Frequency	Who			
Fillet making	Pathogenic micro-organisms	No presence Process should not last more than 1 hour Possible suspicion for contamination should place the product on hold	Determination of the possible consequences in fish from wrong application of the technique	Macroscopic control Temperature recording meters Sampling for microbiological control	For every lot produced in 1 hour	Production staff Production supervisor	Good hygiene Disinfection of tools Temperature control	Processing records	Controlled hygiene and sanitation Temperature measurements
Chilling/ freezing	Parasites	Freezing at –18°C Cooling at 4°C for 24 hours	Temperature of cooling air Time period of ice	Macroscopic fish control Temperature recording meter	Continuous, with macroscopic control at the end of each freezing cycle	Fridges and freezers operator	Maintenance of fridges and freezers Repeat of the process	Temperature control chart for each freezing cycle	Review, control and correction of the records in a week from preparation Recording of the daily temperature inside the fridges
Casing/ marking	Growth of pathogenic micro-organisms Chemical contamination Inadequate marking, weight, dehydration	Products should not be exposed to temperatures over 4°C for more than 3 hours	TTI label per packaged unit	Macroscopic control during packaging and marking before freezing	Every packaged unit	Packaging operator	Placement of labels 1 hour after casing ready to be stored	Verification of TTI records	Internal activation trials for new TTIs, and recording of validation sheets for each order given by the suppliers
Distribution	Possible presence of *Clostridium botulinum* toxin in the packaging with reduced oxygen, if the product is not transported in the right packaging	Time and temperature should not exceed the limit for thermal decomposition of the product	Colour changes showing thermal decomposition	Macroscopic control during storage and distribution	Before storage, distribution and acceptance of packaged product	Packaging operator	Reject/destruct any packaged product exceeding the critical TTI limit	Verification TTI records	Packaging records before distribution showing any product being rejected due to TTI changes

Adapted from Arvanitoyannis and Varzakas (2008).

Table 7.10 ISO 22000 analysis worksheet for determination of some prerequisite programmes for salmon processing.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Receiving of fish	Yes	Yes	No	No	No
Weighing	Yes	Yes	No	Yes	Yes
Grading	Yes	Yes	No	Yes	Yes
Evisceration	Yes	Yes	No	No	No
Blood removal	Yes	Yes	No	No	No
Washing	Yes	Yes	No	Yes	Yes
Sorting	Yes	Yes	No	Yes	Yes
Head removal	Yes	Yes	No	Yes	Yes
Fillet making	Yes	Yes	No	No	No
Skin removal	Yes	Yes	No	Yes	Yes
Dressing	Yes	Yes	No	Yes	Yes
Hanging	Yes	Yes	No	Yes	Yes
Icing	Yes	Yes	No	Yes	Yes
Sorting	Yes	Yes	No	Yes	Yes
Cooling with air or ice	Yes	Yes	No	No	No
Casing	Yes	Yes	No	No	No
Labelling	Yes	Yes	No	Yes	Yes
Freezing	Yes	Yes	No	Yes	Yes
Distribution	Yes	Yes	No	No	No

Adapted from Arvanitoyannis and Varzakas (2008).

Table 7.11 Comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with PRP for salmon processing.

Process step	HACCP CCPs	Prerequisite programme according to ISO 22000?	ISO 22000 CCPs
Receiving of fish	1	No	1
Weighing		Yes	
Grading		Yes	
Evisceration	2	No	2
Blood removal	3	No	
Washing	4	No	
Sorting		Yes	
Head removal		Yes	
Fillet making	5	No	3
Skin removal		Yes	
Dressing		Yes	
Hanging		Yes	
Icing		Yes	
Sorting		Yes	
Cooling with air or ice	6	No	4
Casing	7	No	
Labelling		Yes	
Freezing		Yes	
Distribution	8	No	

process' and so all preparatory operations are 'pre-processing'. The international canned fish market, like most canned food markets, expects that the contents of the can should leave no 'plate-waste' from the consumer. To comply with this expectation, it is necessary to subject the raw material to a variety of pre-processes to bring the fish into the form required in the finished product. Separation of parts, which, even after the prolonged heat exposure of retorting, remain inedible, may take place before any pre-retorting heat treatment.

Although perfectly edible, the skin is removed from many species, especially tuna and mackerel, for presentation purposes. A chemical skinning process is used where fish are briefly immersed in 70–80°C sodium hydroxide solution with a pH of 14. Many canned fish, from sardines to salmon, are not filleted for canning, since their bones after the retorting process are soft enough to eat. Fillets of very oily fish tend to be subject to considerable damage during the filling operation, although the dehydration, associated with the pre-retort cold-smoking operation applied to kipper fillets, makes the flesh firmer and less fragile for easier hand filling.

The main object of brining is the enhancement of flavour in the final product. Normally, the process is short and part of a continuous line from gutting, heading and other separation processes feeding onto can-filling and seaming lines. As such, there is little water removal from the fish during brining. Indeed, in weaker than 80° brines (21% weight to volume NaCl) there may be a net gain in weight.

Removal of water is much faster than with brining but salt penetrating beyond the bounds of taste acceptability limits the time of exposure. Large fish canned in the form of 'cuts' or 'steaks' may be dry salted. Most often applied as a main process for seafood products subsequent to being sold as chilled foods, marinating is also used in the preservation of various shellfish meats in glass jars prior to pasteurisation or sterilisation by heat.

Whether 'hot' or 'cold' smoking is applied, it is essentially a process to impart more flavour to some fatty fish prior to canning. The drying that occurs during the process also denatures and 'sets' the proteins so there is little danger of exudation into the surrounding liquor during the heat process. The initial composition of fatty fish for smoking and canning greatly affects the quality of the end product. Low-fat content raw material tends to lose more water during smoking and, although firm and easily handled at the filling stage, nevertheless remains tough-textured after the heat sterilisation process. On the other hand, high-fat content

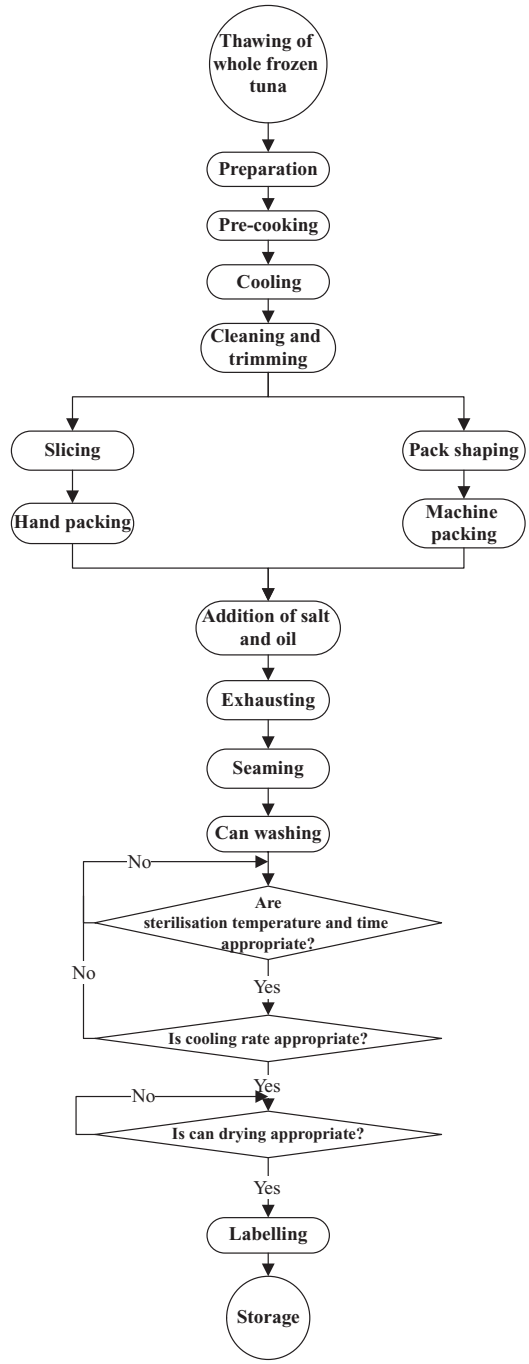

Fig. 7.5 Flow diagram for canning of tuna.

Table 7.12 Canned tuna specifications.

Name of product	Tuna (*Thunnus* spp.)
Country of origin	Greece
Net weight	260 g
Net drained weight	235 g
List of ingredients	Tuna, salt, water/olive oil
Date of minimum durability	18 months
Storage conditions	Store in a cool dark place
Instructions for use	Ready to eat
Manufacturer address	Bluefin Hellas

raw material tends to break up easily during the hand-filling operation and yields a finished product that is too soft.

The heat sterilisation process applied when cans of fish are retorted is more than adequate to cook the contents; indeed, non-fatty, white fish are grossly over-cooked in rendering them commercially sterile and are, therefore, generally unsuitable for canning.

The removal of gases from cans prior to sealing is necessary:

- to prevent large in-container pressures developing during high-temperature sterilisation due to the expansion of headspace gases
- to reduce oxidation of the contents and internal corrosion of the container.

Inequality between internal and external pressures during processing of tin cans causes strain upon the seams, which may cause them to leak.

When packing fish into the container and injecting hot oil, brine or sauce, one can leave less ullage for subsequent expansion and some of the air in the top of the can is expelled by steam from the hot contents. Sealing must follow immediately before cooling and contraction can occur. Solid, chunk, flake and fish-paste packs cannot be satisfactorily exhausted, although attempts have been made to fill solids cold and inject hot liquid. The resultant headspace vacuum in such cases may be lower than 5 mm of mercury so that there is a danger that the can ends flip outwards.

Containers that are conveyed through a steam-exhausting chamber and sealed as they emerge have their headspace air replaced by steam, which condenses in the closed container. The most reliable method of achieving a constant headspace vacuum is to seal the can in an evacuated chamber. However, the speed at which lines can run may be retarded by the time needed to exhaust the cans as they enter the chamber.

It is desirable that neither flesh nor liquid be trapped in the seal during the sealing stage, as trapped material may provide a route for post-process contamination and in the case of glass pry-offs, which rely upon internal vacuum to hold on the lid during processing, total failure of the seal. By far the majority of incidences of canned food spoilage by micro-organisms are traceable to re-infection of the contents after processing usually by ingress through the double seam. This is called 'leaker spoilage'. Non-destructive visual and tactile examination of can seams may detect a fault in the seaming operation. Such faults and their detection are described in can-markers' manuals. 'Droop', 'spurs', 'cutcover', 'jumped seams' and 'false seams' are common descriptions of faults arising from either the use of damaged cans or the erroneous setting of the seaming equipment (Hall, 1997).

The pre-cooking of scombroid species is carried out in steam under atmospheric pressure for times that vary according to the size of the fish; 0.25 kg mackerel, for example, requires only 30 minutes, while large 20 kg tuna may require four hours. In the former case, the mackerel are often cooked in the open can followed by decanting of the separated liquor, sauce or oil, sealing and retorting. All skin must be painstakingly removed for the sake of pack presentation, and remaining flesh is packed as a solid steak, as chunks or as flakes, by hand or machine. In the latter two cases, this involves moulding the pieces into the correct shape, cutting and compressing them into the can. The portions thus formed are discharged into cans. In general, the fish and sauce content amount to 60 and 40%, respectively. The flow diagram for the canning of tuna is given in Fig. 7.5. The canned tuna specifications are described in Table 7.12. The HACCP plans (preventive measures and corrective actions) are summarised in Tables 7.13 and 7.14, respectively. The questions used to derive a CCP for canned tuna according to HACCP analysis are given in Table 7.15. The ISO 22000 analysis worksheet for determination of some PRPs for canned tuna is summarised in Table 7.16 and the comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with PRPs is given in Table 7.17. The flow diagram for the packing of mackerel as skinless fillets in a variety of sauces is shown in Fig. 7.6 and the fish fillets specifications are summarised in Table 7.18. The questions answered to determine a CCP for the packing of mackerel as skinless fillets in a variety of sauces according to HACCP analysis are given in Table 7.19. The ISO

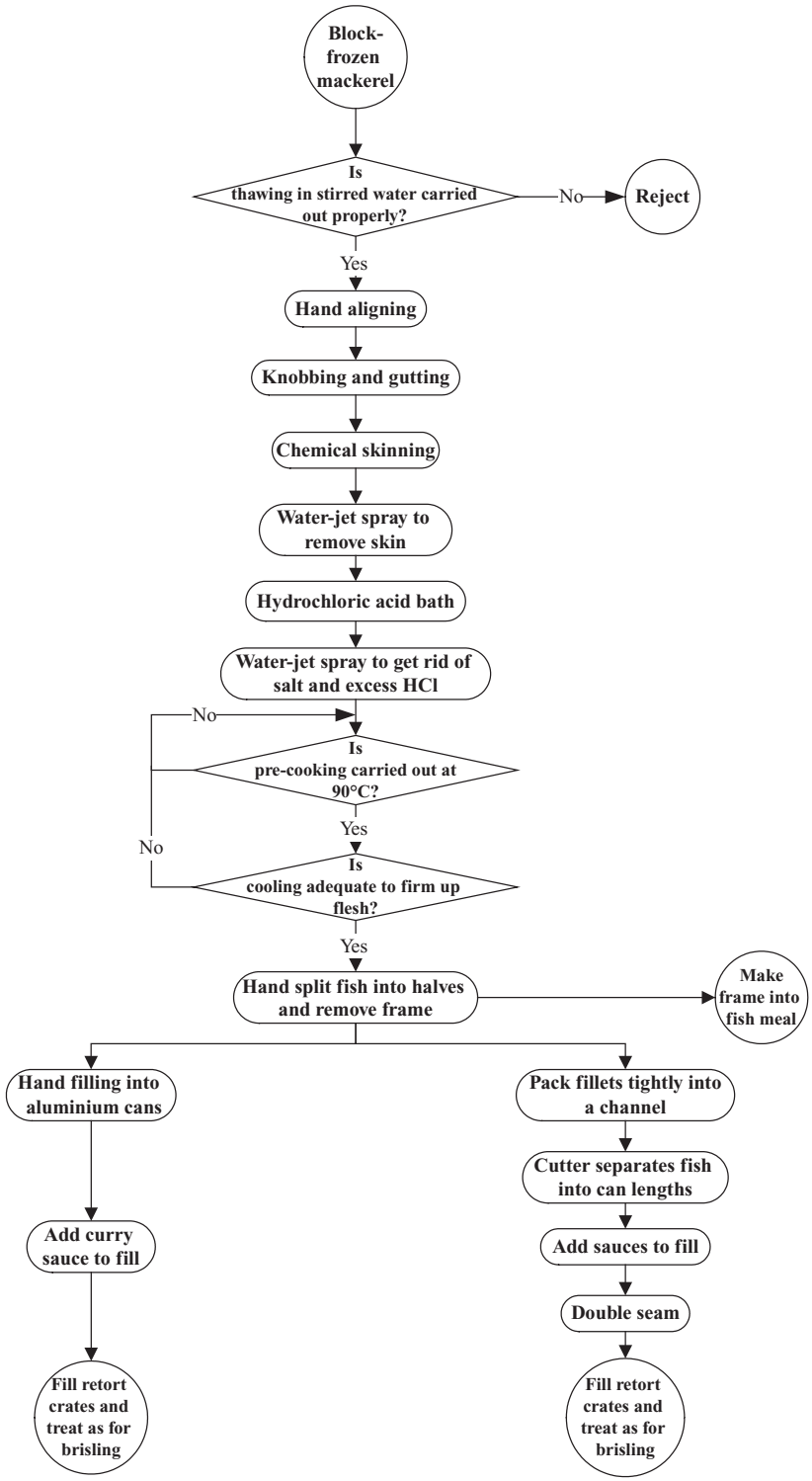

Fig. 7.6 Flow diagram for the packing of mackerel as skinless fillets in a variety of sauces.

22000 analysis worksheet for determination of some PRPs for the packing of mackerel as skinless fillets in a variety of sauces is summarised in Table 7.20 and the comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with PRPs is given in Table 7.21. The flow diagram for the production of canned pickled mussels is given in Fig. 7.7 and the mussel specification is summarised in Table 7.22. The questions answered to derive a CCP for pickled mussels according to HACCP analysis are given in Table 7.23. The ISO 22000 analysis worksheet for determination of some PRPs for pickled mussels is summarised in Table 7.24 and the comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with PRPs is given in Table 7.25. The potential CCPs of seafood are summarised in Table 7.26.

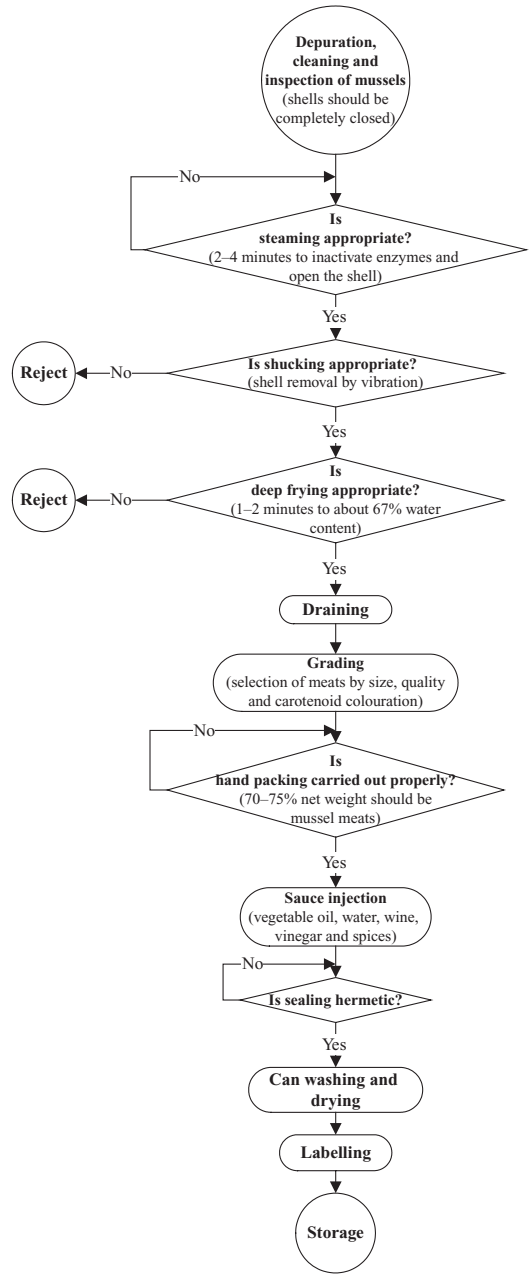

Fig. 7.7 Flow diagram for production of canned pickled mussels.

7.12 PRAWNS

Prawns are produced by both wild catch and aquaculture. Prawns are bottom-feeding, opportunistic omnivores, and will consume a wide variety of foods depending on availability. Apart from the hazards introduced from the environment, further hazards can also be introduced during subsequent processing, handling, transport and storage stages.

A range of prawn species are commercially harvested as wild catch in Australia, from both estuarine and marine environments. Catch is obtained from a wide range of locations, covering much of the Australian coastline. The primary method of catch is demersal otter trawling.

Significant chemical hazards originating from the environment include the metals, arsenic and mercury (ANZFA, 2005). Both of these are recognised as human toxins, and their presence in crustacea is regulated under the New Food Standards Code (ANZFA, 2005). Cadmium has also been identified as a food safety hazard associated particularly with endeavour prawns (*Metapenaeus* spp.) harvested in certain geographical regions (ANZFA, 2005).

Prawns are also potentially exposed to a range of indigenous microbial contaminants from the water environment, including *A. hydrophila*, *V. parahaemolyticus*, *V. vulnificus*, *V. cholerae*, *Salmonella* spp. and *L. monocytogenes*. *Vibrios* are known to utilise the chitinous exoskeleton of crustacea as points of attachment and to metabolise it as a carbon/energy source. *V. parahaemolyticus*, *V. vulnificus* and *V. cholerae* are considered part of the indigenous microflora of estuarine prawns.

V. cholerae O1 and O139 and *Salmonella* spp. derived from faecal contamination may become established as environmental contaminants in waters from which prawns are harvested and have the potential to contaminate free-living prawns prior to catch.

Noroviruses and hepatitis A may also be present. Prawns inhabiting estuarine environments may be

Table 7.13 HACCP plan for canned tuna (preventive measures).

Processing step	Hazard	CCP	Preventive measures	Monitoring
Thawing of whole frozen tuna	Decomposed fish Damaged fish	Receiving area	Control supply source Product temperature history	Measure temperature upon receipt Visual inspection Sample for histamine testing
Preparation	Decomposed fish Histamine	Cleaning	Control temperature of fish Control lag time from end of thaw to end of preparation	Backbone temperature Sensory inspection Histamine analysis
Loin cleaning	Green meat, orange meat	Loin cleaning tables	End of cooling Control time of loin cleaning and hygienic practices Train workers to detect loin	Temperature and time of cooling Visual inspection Sanitation inspection
Hand packing	Defect empty can Over filling	Empty can storage area Weighing table	Select can suppliers Train workers on container integrity Adjust packing machine Calibrate balance and weigh used	Visual and seam tear down inspection upon arrival On-line weigh check/calibration
Seaming	Defective double seam	Seamer	Adjustment of seamer Train QC/seam mechanic	Visual seam inspection Seam tear down
Drying	Improper processing (lower temperature, less time) resulting in outgrowth of microbes and toxins	Drying area	Train operators Equipment checked and calibrated Close surveillance of operations (by QC/QA)	All thermal processes Operations
Post-process handling	Post-process contamination	Cooling zone	Restrict area Traffic control Sanitation	Check admittance to area (visual inspection) Daily sanitation check

exposed to a greater number of potential sources of microbial or chemical contamination, due to their proximity to shore, land animals, human dwellings, and the introduction of chemical and faecal pollutants.

After harvest, prawns caught on commercial vessels can be processed in a variety of ways. While on board, they may be boxed as green (uncooked) product and chilled or frozen on board. In some operations, catch is cooked on board vessels, and subsequently stored in either brine or ice. Dipping of prawns in metabisulphite to inhibit formation of black spot can present a risk to asthmatics due to formation of sulphur dioxide (ANZFA, 2005).

The processing of prawns on board vessels presents considerable potential for further contamination. Raw product may come into contact with chemical or microbial contaminants through contact with water, surfaces or containers. Pathogens of concern include *V. cholerae*, *V. parahaemolyticus*, *E. coli*, *Campylobacter*, *Shigella*, *Yersinia* and *Salmonella* spp. and *L. monocytogenes*. Human handling also introduces potential for contamination by enteric pathogens such as *Salmonella*, *S. aureus*, hepatitis A virus and noroviruses.

Prawns that undergo a cooking step are effectively rendered pathogen free, as any micro-organisms present will be inactivated, assuming that the product is heated at sufficient temperature and time. However, cooking will not remove or inactivate chemical hazards already present in the product, such as

Table 7.14 HACCP plan for canned tuna (corrective actions).

Processing step	Critical limits	Corrective actions	Verification	Records
Thawing of whole frozen tuna	Frozen fish $< -18^{\circ}C$ Fresh fish $\sim 0^{\circ}C$ Histamine <50 ppm	Inform/change supplier If histamine >50 ppm, increase surveillance at preparation	Annually, conduct survey of supplier handling system Histamine/temperature relationships	Suppliers temperature record Raw materials receiving record Supplier sources and history
Preparation	Histamine <50 ppm Fish temperature 0–5°C Lag time according to specifications (2 hours)	If >10% grade 3 fish, lot should be individually culled If >10% grade 4 (rejected) fish found, lot should be rejected If histamine >50 ppm, increase surveillance Inform supplier Reduce volume on line	Samples for sensory and histamine analysis Check graders' competence with histamine determination	Raw fish grading form Chemical analysis form Training record
Loin cleaning	Lag time not >6 hours No defect or decomposed loin Sanitation: visually accepted	If lag time exceed limits, fish should be put in chilled room for any anticipated delay Increase surveillance at preparation table Improve cleaning and sanitation	Control histamine/temperature relationship Check samples on workers and graders Plant sanitation inspection daily	Cooling time and temperature record Loin quality record Training record
Hand packing	Pending on establishment	If more than acceptance no adjustment in packing machine	Inspection of performance and practices and records	Record of empty can manufacturers audit Empty can inspection record Can specifications
Seaming	As determined in initial verification according to size of can	Stopping machine for maintenance and adjustment	Inspection of performance and practices	Seamer inspection report Seam tear down report
Drying	As determined in initial verification	Hold lot/reprocess lot	Periodic control on heat distribution in retort and temperature recording equipment Check operation competence Record review daily	Retort operation record Temperature recording charts
Post-process handling	Entrance to authorised personnel only	Stop unauthorised entry	Inspection of traffic control programme On-site verification	Product control report

arsenic, mercury and other chemical residues. Cross-contamination between raw and processed crustaceans during processing, transport and storage, particularly on board vessels, is recognised as an area of particular concern, potentially reintroducing environmental microbial hazards. Cooling water and brine/ice used for storage of prawns are also recognised as potential sources of recontamination. Cooked crustacea may also be contaminated by food handlers, introducing enteric pathogens.

Table 7.15 Questions used to determine CCPs for canning of tuna according to HACCP analysis.

Processing step	Determination of hazards	Do preventative control measures exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable level(s)?	Will a subsequent step eliminate identified hazard(s) or reduce likely occurrence to acceptable levels?	Is this stepping a critical control point?
Thawing of whole frozen tuna	Biological: Pathogenic micro-organisms, parasites	Yes	No	Yes	No	
	Chemical: Heavy metals, pesticide residues	Yes	No	Yes	No	
	Physical: Extrinsic deformations, bruises	Yes	No	Yes	No	
Preparation	Biological: No identified hazard	No	No	No	Yes	
	Chemical: No identified hazard	No	No	No	Yes	
	Physical: No identified hazard	No	No	No	Yes	
Pre-cooking	Biological: Microbial infection, parasites	Yes	No	Yes	No	
	Chemical: No identified hazard	No	No	No	Yes	
	Physical: Foreign materials	Yes	No	Yes	No	
Cooling	Biological: Microbial infection, parasites	Yes	No	Yes	No	
	Chemical: No identified hazard	Yes	No	Yes	Yes	
	Physical: No identified hazard	Yes	No	Yes	Yes	
Cleaning and trimming	Biological: Water infected with pathogenic micro-organisms	Yes	Yes	—	—	
	Chemical: Infectious agents in water	Yes	Yes	—	—	
	Physical: Foreign matter	Yes	Yes	—	—	
Slicing	Biological: Microbial contamination	Yes	Yes	—	—	CCP1
	Chemical: No identified hazard	Yes	Yes	—	—	
	Physical: No identified hazard	Yes	Yes	—	—	

Table 7.15 (Continued)

Processing step	Determination of hazards	Do preventative control measures exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable level(s)?	Will a subsequent step eliminate identified hazard(s) or reduce likely occurrence to acceptable levels?	Is this stepping a critical control point?
Hand packing	Biological: Microbial contamination	Yes	Yes	—	—	CCP2
	Chemical: No identified hazard	Yes	Yes	—	—	
	Physical: Foreign matter	Yes	Yes	—	—	
Addition of salt and oil	Biological: No identified hazard	Yes	No	No	—	
	Chemical: Chemical contamination	Yes	No	No	—	
	Physical: No identified hazard	Yes	No	No	Yes	
Exhausting	Biological: Microbial contamination, parasites	Yes	No	Yes	No	
	Chemical: No identified hazard	Yes	No	No	No	
	Physical: No identified hazard	Yes	No	No	No	
Seaming	Biological: No identified hazard	Yes	No	No	Yes	CCP3
	Chemical: Chemical contamination	Yes	No	No	Yes	
	Physical: No identified hazard	Yes	No	No	Yes	
Can washing	Biological: Growth of pathogenic micro-organisms	No	No	Yes	Yes	
	Chemical: Can chemical compounds	No	No	Yes	Yes	
	Physical: No potable water	No	No	No	Yes	
Heat sterilisation	Biological: Growth of pathogenic micro-organisms	No	No	No	Yes	CCP4
	Chemical: Can chemical compounds	No	No	No	Yes	
	Physical: No identified hazard	No	No	No	Yes	

(*Continues*)

Table 7.15 (Continued)

Processing step	Determination of hazards	Do preventative control measures exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable level(s)?	Will a subsequent step eliminate identified hazard(s) or reduce likely occurrence to acceptable levels?	Is this stepping a critical control point?
Cooling	Biological: Microbial infection	No	No	No	Yes	CCP5
	Chemical: No identified hazard	No	No	No	Yes	
	Physical: No identified hazard	No	No	No	Yes	
Labelling	Biological: No identified hazard	Yes	Yes	No	No	CCP6
	Chemical: No identified hazard	Yes	Yes	No	No	
	Physical: No identified hazard	Yes	Yes	No	No	
Storage	Biological: Growth of micro-organisms, parasites	Yes	Yes	—	—	CCP7
	Chemical: Rare	—	—	—	—	
	Physical: Foreign matter	Yes	No	No	—	

Use of low temperatures (below 5°C) during transport and storage (of both raw and cooked product), as well as during processing, will reduce the opportunities for growth of most microbial contaminants; however, some pathogens are able to proliferate at these temperatures: *V. cholerae* will grow at 8°C; *V. parahaemolyticus* can grow at 5°C; and *L. monocytogenes* is able to grow at temperatures as low as −0.4°C.

Once frozen, no further microbial growth can occur, and many pathogens will decline in number with prolonged frozen storage. However, survival rates in frozen crustacea are variable. Time/temperature abuse of thawed product can provide opportunity for growth of any bacterial pathogens that have survived freezing.

In some situations, periods of several days may elapse between cooking of prawns and consumption. This time delay provides potential opportunities for outgrowth and further contamination with microbial pathogens, particularly *L. monocytogenes*.

Cooked crustacea such as prawns are frequently added to cold dishes which receive only warming, and which are then potentially subject to time/temperature abuse. This may allow bacterial growth and toxin production by contaminating *S. aureus*. Toxin production may also be enhanced if the seafood is part of a dish with a starch component (ANZFA, 2005).

Prawn production through aquaculture has been established for the last 15 years along the eastern coastline of Australia and in the Northern Territory. Australian prawn farms are restricted to the coastal zone, virtually all drawing their intake water from tidal creeks and estuaries. Harvesting and post-harvest treatments are species specific. Currently, Australia grows two species of prawns: the black tiger prawn (*Penaeus monodon*) and the Japanese king or kuruma prawn (*P. japonicus*). The black tiger prawn is mostly sold on local Brisbane, Sydney and Melbourne markets, either fresh, frozen or cooked. Typically, black tiger prawns are harvested en–masse with a drain harvest, and then chilled or cooked on site before being shipped to domestic markets. The kuruma prawn is grown exclusively for the live trade in Japan.

Table 7.16 ISO 22000 analysis worksheet for determination of some prerequisite programmes for canning of tuna.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Thawing of whole frozen tuna	Yes	Yes	No	No	No
Preparation	Yes	Yes	No	No	No
Pre-cooking	Yes	Yes	No	No	No
Cooling	Yes	Yes	No	Yes	Yes
Cleaning and trimming	Yes	Yes	No	Yes	Yes
Slicing	Yes	Yes	No	Yes	Yes
Hand packing	Yes	Yes	No	Yes	Yes
Addition of salt and oil	Yes	Yes	No	Yes	Yes
Exhausting	Yes	Yes	No	Yes	Yes
Seaming	Yes	Yes	No	Yes	Yes
Can washing	Yes	Yes	No	Yes	Yes
Heat sterilisation	Yes	Yes	No	No	No
Cooling	Yes	Yes	No	No	No
Drying	Yes	Yes	No	Yes	Yes
Labelling	Yes	Yes	No	No	No
Storage	Yes	Yes	No	Yes	Yes

Like wild-caught prawns, prawns produced through aquaculture may be exposed to various hazards through their water environment. These potential hazards are largely the same as for wild-caught prawns inhabiting estuarine environments, as described above. In intensive aquaculture systems, *Vibrio* and *Salmonella* species are considered to be inherent contaminants of prawns (ANZFA, 2005). The flow diagram for processing of ready-to-eat dehusked prawns is shown in Fig. 7.8. The questions used to derive a CCP for ready-to-eat dehusked prawns according to HACCP analysis are given in Table 7.27. The CCPs, hazards, critical limits, corrective actions and records and the ISO 22000 analysis worksheet for

Table 7.17 Comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with PRP for canning of tuna.

Process step	HACCP CCPs	Prerequisite programme according to ISO 22000?	ISO 22000 CCPs
Thawing of whole frozen tuna		No	
Preparation		No	
Pre-cooking		No	
Cooling		Yes	
Cleaning and trimming		Yes	
Slicing	1	Yes	
Hand packing	2	Yes	
Addition of salt and oil		Yes	
Exhausting		Yes	
Seaming	3	Yes	
Can washing		Yes	
Heat sterilisation	4	No	1
Cooling	5	No	2
Drying	6	Yes	
Labelling		No	
Storage	7	Yes	

determination of some PRPs for ready-to-eat dehusked prawns are summarised in Table 7.28 and Table 7.29, respectively. The comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with PRPs for ready-to-eat dehusked prawns is given in Table 7.30.

7.13 LOBSTERS

Lobsters inhabit similar marine environments to prawns, and are potentially exposed to the same environmental hazards, both chemical and microbial. Raw and frozen product is also subject to similar processing and similar potential hazards. Endogenous bacteria that are human pathogens (e.g. *Vibrio*s and *A. hydrophila*) and environmental contaminants (arsenic and mercury) are potential hazards. Post-harvest handling, processing, transport and storage potentially introduce and allow outgrowth of human enteric pathogens (*E. coli*, *S. aureus*, *Campylobacter*, *Shigella*, *Yersinia* and *Salmonella* spp., and noroviruses and hepatitis A virus) and *L. monocytogenes*. However, as lobster is generally sold either as live or as raw frozen product, and is generally cooked thoroughly just before eating, concerns regarding microbiological contamination of cooked product prior to consumption are less relevant.

7.14 CRABS

Fisheries for two commercial crab species in Australia (Spanner and Blue Swimmer crabs) are found in Queensland, New South Wales and Western Australia. These are caught in both estuarine and marine waters, using baited tangle nets, or in traps, hoop nets or dragnets.

When moving as large aggregations, Spanner crabs are also occasionally caught as a by-product of demersal otter trawling operations. Cadmium has been identified as a food safety hazard associated particularly with Spanner crabs (*Ranina ranina*).

Crabs inhabit similar estuarine and marine environments to prawns, and are potentially exposed to the same environmental hazards, both chemical and microbial. Raw and frozen product is also subject to similar processing and similar potential hazards. Endogenous bacteria that are human pathogens (e.g. *Vibrio*s and *A. hydrophila*) and environmental contaminants (arsenic and mercury) are potential hazards. Post-harvest handling, processing, transport and storage potentially introduce and allow outgrowth of human enteric pathogens (*E. coli*, *Campylobacter*, *Shigella*, *Yersinia* and *Salmonella* spp., and noroviruses and hepatitis A virus) and *L. monocytogenes*. However, as crab is generally sold either as live or raw frozen product, and is generally cooked thoroughly just before eating, concerns regarding microbiological contamination of cooked product prior to consumption are less relevant than for cooked prawns (ANZFA, 2005). The flow diagram of cooked crabs is shown in Fig. 7.9 and the cooked crab specifications are given in Table 7.31. The questions asked to derive a CCP for cooked crabs according to HACCP analysis are given in Table 7.32. The ISO 22000 analysis worksheet for determination of some PRPs for cooked crabs is summarised in Table 7.33 and the comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with PRPs is given in Table 7.34.

Table 7.18 Fish fillets specifications.

Firm name	ABC Fish Company
Firm address	Anywhere, USA
Raw material	Arrowtooth flounder (*Atheresthes stomias*), dover sole (*Microstomus pacificus*), English sole (*Pleuronectes vetulus*), lingcod (*Ophiodon elongates*), pacific cod (*Gadus macrocephalus*), pacific whiting (*Merluccius* spp.), pacific sanddab (*Citharichthys sordidus*), Pollock (*Theragra chalcogramma*), rockfish (*Sebastes* spp.), thornyhead/rockcod (*Sebastolobus* spp.)
Finished product	Fillets, fresh and frozen
Packaging	Air packaged
Method of distribution and storage	Distributed and stored frozen, in ice or under refrigeration
Intended use and consumer	To be fully cooked before consumption by the general public

7.15 COOKED FISH AND SHELLFISH

Shellfish are transported to processing sites chilled, sometimes on ice and then washed prior to cooking. With the exception of some molluscan shellfish, e.g. cockles and mussels, shellfish are rarely cooked to temperatures in excess of 75–80°C as the meat becomes very tough if cooked for too long or at too high a temperature. Bivalve molluscs such as cockles and mussels are often cooked at temperatures in excess of 90°C for 90 seconds. Typical heat processes for other shellfish reach 70–72°C for less than two minutes. After cooking and chilling, shellfish are packed into bulk

Table 7.19 Questions used to determine CCPs for filleting of mackerel according to HACCP analysis.

Processing step	Determination of hazards	Do preventative control measures exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable level(s)?	Will a subsequent step eliminate identified hazard(s) or reduce likely occurrence to acceptable levels?	Is this step a critical control point?
Block-frozen mackerel	Biological: Pathogenic micro-organisms, parasites	Yes	No	—	—	CCP1
	Chemical: Heavy metals, pesticide residues	Yes	No	Yes	No	
	Physical: Extrinsic deformations, bruises	Yes	No	Yes	No	
Thawing in agitated water	Biological: Pathogenic micro-organisms, parasites	No	No	No	Yes	
	Chemical: Pesticide residues	No	No	No	Yes	
	Physical: No identified hazard	No	No	No	Yes	
Hand aligning	Biological: Microbial infection, parasites	Yes	No	Yes	No	CCP2
	Chemical: No identified hazard	No	No	No	Yes	
	Physical: Foreign materials	Yes	No	Yes	No	
Knobbing and gutting	Biological: Microbial infection, parasites	Yes	No	Yes	No	
	Chemical: No identified hazard	Yes	No	Yes	Yes	
	Physical: No identified hazard	Yes	No	Yes	Yes	
Chemical skinning	Biological: Water infected with pathogenic micro-organisms	Yes	Yes	—	—	CCP3
	Chemical: Heavy metals, pesticide residues	Yes	Yes	—	—	
	Physical: Foreign matter	Yes	Yes	—	—	
Water-jet spray to remove skin	Biological: Microbial contamination	Yes	Yes	—	—	
	Chemical: No identified hazard	Yes	Yes	—	—	
	Physical: No identified hazard	Yes	Yes	—	—	

(*Continues*)

Table 7.19 (Continued)

Processing step	Determination of hazards	Do preventative control measures exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable level(s)?	Will a subsequent step eliminate identified hazard(s) or reduce likely occurrence to acceptable levels?	Is this step a critical control point?
Hydrochloric acid bath	Biological: Microbial contamination	Yes	Yes	—	—	
	Chemical: Chemical contamination	Yes	Yes	—	—	
	Physical: Foreign matter	Yes	Yes	—	—	
Water-jet spray to remove of salt and excess HCl	Biological: No identified hazard	Yes	No	No	—	
	Chemical: Chemical contamination	Yes	No	No	—	
	Physical: No identified hazard	Yes	No	No	Yes	
Pre-cooking	Biological: Microbial contamination, parasites	Yes	No	Yes	No	CCP4
	Chemical: No identified hazard	Yes	No	No	No	
	Physical: No identified hazard	Yes	No	No	No	
Cooling	Biological: Microbial contamination, parasites	Yes	No	No	Yes	CCP5
	Chemical: No identified hazard	Yes	No	No	Yes	
	Physical: No identified hazard	Yes	No	No	Yes	
Hand split fish into halves and remove frame	Biological: Growth of pathogenic micro-organisms	No	No	Yes	Yes	CCP6
	Chemical: No identified hazard	No	No	Yes	Yes	
	Physical: No identified hazard	No	No	No	Yes	
Canning	Biological: Growth of pathogenic micro-organisms	No	No	No	Yes	
	Chemical: Can chemical compounds	No	No	No	Yes	
	Physical: No identified hazard	No	No	No	Yes	

Table 7.19 (Continued)

Processing step	Determination of hazards	Do preventative control measures exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable level(s)?	Will a subsequent step eliminate identified hazard(s) or reduce likely occurrence to acceptable levels?	Is this step a critical control point?
Add sauce to fill	Biological: Microbial infection.	No	No	No	Yes	
	Chemical: Chemical compounds	No	No	No	Yes	
	Physical: Foreign matter	No	No	No	Yes	
Storage	Biological: Growth of micro-organisms, parasites	Yes	Yes	—	—	CCP7
	Chemical: Rare	—	—	—	—	
	Physical: Foreign matter	Yes	No	No	—	

Table 7.20 ISO 22000 analysis worksheet for determination of some prerequisite programmes for filleting of mackerel.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Block-frozen mackerel	Yes	Yes	No	No	No
Thawing in agitated water	Yes	Yes	No	Yes	Yes
Hand aligning	Yes	Yes	No	No	No
Knobbing and gutting	Yes	Yes	No	Yes	Yes
Chemical skinning	Yes	Yes	No	No	No
Water-jet spray to remove skin	Yes	Yes	No	Yes	Yes
Hydrochloric acid bath	Yes	Yes	No	Yes	Yes
Water-jet spray to remove salt and excess HCl	Yes	Yes	No	Yes	Yes
Pre-cooking	Yes	Yes	No	No	No
Cooling	Yes	Yes	No	No	No
Hand split fish into halves and remove frame	Yes	Yes	No	No	No
Canning	Yes	Yes	No	Yes	Yes
Add sauce to fill	Yes	Yes	No	Yes	Yes
Storage	Yes	Yes	No	No	No

Table 7.21 Comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with PRP for filleting of mackerel.

Process step	HACCP CCPs	Prerequisite programme according to ISO 22000?	ISO 22000 CCPs
Block-frozen mackerel	1	No	
Thawing in agitated water		Yes	
Hand aligning	2	No	
Knobbing and gutting		Yes	
Chemical skinning	3	No	1
Water-jet spray to remove skin		Yes	
Hydrochloric acid bath		Yes	
Water-jet spray to remove salt and excess HCl		Yes	
Pre-cooking	4	No	
Cooling	5	No	2
Hand split fish into halves and remove frame	6	No	
Canning		Yes	
Add sauce to fill		Yes	
Storage	7	No	3

packs which may be gas flushed for distribution to retail stores where they may be displayed on the fish counter, usually in open containers on beds of ice. Unless packed under modified atmosphere or cooked in pack, shellfish will have a shelf life or less than 10 days under refrigerated conditions (Bell and Kyriakides, 2000).

However, shellfish cooked in pack and those stored under modified atmospheres may have allocated shelf lives of more than 10 days. The fish is usually gutted and filleted prior to cooking and it may also have the skin removed. Fish may be cooked whole, coated in batter and crumbs and flash fried or it may be minced and reformed with other ingredients into different shapes and sizes prior to cooking. The cooking process for both fish and shellfish is not designed to destroy spores of *Cl. botulinum*. However, as most chilled, cooked fish and shellfish have shelf lives of less than 7 days; the hazard presented by this organism is minimal providing effective temperature control is maintained (Peterson *et al*., 1997).

In principle, products receiving a non-proteolytic 'botulinum cook' can be safely stored under refrigeration for long periods without compromising safety. However, it is important to note that as the spores of proteolytic strains of *Cl. botulinum* will remain unaffected by the pasteurisation processes employed to destroy non-proteolytic strains, any temperature abuse during the shelf life may result in an unsafe product. It is essential that products cooked in pack and given extended shelf lives under chilled conditions should be prominently labelled 'keep refrigerated' in an attempt to prevent outbreaks occurring from surviving spores, other than non-proteolytic *Cl. botulinum* (Bell and Kyriakides, 2000).

7.16 SMOKED READY-TO-EAT FISH

Fish and shellfish are known to be contaminated with *Cl. botulinum* although the frequency and types will vary according to the source of the material. Marine sediments are frequently found to contain the organism and the fish may become contaminated during its normal life cycle or during the catching or processing. Fish may be contaminated on the external surfaces but it is most common to find the organism in the intestinal contents. The type most commonly associated with marine sediments and therefore also with the fish is *Cl. botulinum* type E. As strains of this type can grow psychotropically, it is evident why chilled, long shelf life products of this nature are of particular concern with regard to the potential hazard posed by this organism (Bell and Kyriakides, 2000).

Table 7.22 Canned pickled mussels specifications.

Aquatic product raw material	Mussels (*Modiolus* spp., *Mytilus* spp. and/or *Perna canaliculus*)
Raw material harvest area	California, Oregon, Washington, Alaska
Raw material received	Directly from harvester
Finished product	Canned pickled mussels
Food additives, ingredients, processing aids	Sauce, salt
Shipping	Shipped in the firm's trucks
Intended use	Consumed as it is (ready-to-eat product) or fully cooked
Intended consumers	General public

Table 7.23 Questions used to determine CCPs for production of canned pickled mussels according to HACCP analysis.

Processing step	Determination of hazards	Do preventative control measures exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable level(s)?	Will a subsequent step eliminate identified hazard(s) or reduce likely occurrence to acceptable levels?	Is this step a critical control point?
Depuration, cleaning and inspection of mussels	Biological: Pathogenic micro-organisms, parasites	Yes	No	—	—	CCP1
	Chemical: Heavy metals, pesticide residues	Yes	No	Yes	No	
	Physical: No potable water	Yes	No	Yes	No	
Steaming	Biological: Pathogenic micro-organisms, parasites	No	No	No	Yes	CCP2
	Chemical: No identified hazard	No	No	No	Yes	
	Physical: No potable water	No	No	No	Yes	
Shucking	Biological: Microbial infection, parasites	Yes	No	Yes	No	CCP3
	Chemical: No identified hazard	No	No	No	Yes	
	Physical: Foreign materials	Yes	No	Yes	No	
Deep frying	Biological: Microbial infection, parasites	Yes	No	Yes	No	CCP4
	Chemical: No identified hazard	Yes	No	Yes	Yes	
	Physical: No potable water	Yes	No	Yes	Yes	
Draining	Biological: Water infected with pathogenic micro-organisms	Yes	Yes	—	—	
	Chemical: No identified hazard	Yes	Yes	—	—	
	Physical: No identified hazard	Yes	Yes	—	—	
Grading	Biological: Microbial contamination	Yes	Yes	—	—	
	Chemical: Colour compounds	Yes	Yes	—	—	
	Physical: No identified hazard	Yes	Yes	—	—	

(*Continues*)

Table 7.23 (Continued)

Processing step	Determination of hazards	Do preventative control measures exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable level(s)?	Will a subsequent step eliminate identified hazard(s) or reduce likely occurrence to acceptable levels?	Is this step a critical control point?
Hand packing	Biological: Microbial contamination	Yes	Yes	—	—	CCP5
	Chemical: No identified hazard	Yes	Yes	—	—	
	Physical: Foreign matter	Yes	Yes	—	—	
Sauce injection	Biological: Microbial contamination	Yes	No	No	—	
	Chemical: Chemical contamination	Yes	No	No	—	
	Physical: Foreign matter	Yes	No	No	Yes	
Sealing	Biological: Microbial contamination, parasites	Yes	No	Yes	No	CCP6
	Chemical: Chemical contamination	Yes	No	No	No	
	Physical: No identified hazard	Yes	No	No	No	
Can washing and drying	Biological: Microbial contamination, parasites	Yes	No	No	Yes	
	Chemical: Can chemical compounds	Yes	No	No	Yes	
	Physical: No identified hazard	Yes	No	No	Yes	
Labelling	Biological: No identified hazard	No	No	Yes	Yes	
	Chemical: No identified hazard	No	No	Yes	Yes	
	Physical: No identified hazard	No	No	No	Yes	
Storage	Biological: Growth of pathogenic micro-organisms	No	No	No	Yes	
	Chemical: No identified hazard	No	No	No	Yes	
	Physical: No identified hazard	No	No	No	Yes	

Table 7.24 ISO 22000 analysis worksheet for determination of some prerequisite programmes for production of canned pickled mussels.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Depuration, cleaning and inspection of mussels	Yes	Yes	No	No	No
Steaming	Yes	Yes	No	No	No
Shucking	Yes	Yes	No	No	No
Deep frying	Yes	Yes	No	No	No
Draining	Yes	Yes	No	Yes	Yes
Grading	Yes	Yes	No	Yes	Yes
Hand packing	Yes	Yes	No	No	No
Sauce injection	Yes	Yes	No	Yes	Yes
Sealing	Yes	Yes	No	No	No
Can washing and drying	Yes	Yes	No	Yes	Yes
Labelling	Yes	Yes	No	Yes	Yes
Storage	Yes	Yes	No	Yes	Yes

In a survey of aquatic environments including lakes, ponds, reservoirs, marshes, mud flats, streams, rivers and canals in Great Britain and Ireland, Smith *et al.* (1978) did not find any *Cl. botulinum* type A in 554 samples of mud. Cann *et al.* (1965) found little evidence of type E strains in the North Sea but, in contrast, a high proportion of samples from deposits around the Scandinavian coast were found to contain the organism. Huss *et al.* (1974) demonstrated a high incidence of *Cl. botulinum* type E in trout farms in Denmark. A total of 530 trout were examined with incidence varying from 5 to 100% in the winter and 85 to 100% in late summer. The levels of *Cl. botulinum* can be very high, particularly in farmed fish sediments where the organism can enter via the fish food and proliferate in any dead fish. Indeed, botulism outbreaks in fish

Table 7.25 Comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with PRP for production of canned pickled mussels.

Process step	HACCP CCPs	Prerequisite programme according to ISO 22000?	ISO 22000 CCPs
Depuration, cleaning and inspection of mussels	1	No	
Steaming	2	No	
Shucking	3	No	1
Deep frying	4	No	2
Draining		Yes	
Grading		Yes	
Hand packing	5	No	
Sauce injection		Yes	
Sealing	6	No	
Can washing and drying		Yes	
Labelling		Yes	
Storage		Yes	

Table 7.26 Potential critical control points (CCPs) of seafood.

Items	Hazards	CCPs
1. Fish	Health and safety risks	*Prior to processing* Unloading dock Receiving room – cool room
2. Other ingredients	Contamination of products with unapproved, unsafe compounds Use of compounds not meeting specifications; misapplication	*Prior to use* When received Before application or use Application area
3. Packaging material	Use of unapproved, damaged or unclean containers	*Prior to use* Packing area When received Immediately before use
4. Labels	Information not consistent with regulations	*Prior to use* Before application When received
5. Cleaning agents, sanitisers, lubricants	Contamination of product with unapproved, unsafe chemicals; misapplication	*Prior to use* When received Before application During application at application area
6. Construction/maintenance of production facilities/processing equipment	Contamination of product due to faulty construction of plant or equipment	*Prior to start-up/during operation* Twice per operating season Weekly evaluations at CCPs
7. Operation and sanitation	Contamination of product due to poor operation and sanitation practices	*Prior to start-up/during operation* Once per 3 months of operation Daily sanitation checks
8. Process control	Production of product that does not comply with safety, quality, wholesomeness and/or fair trade requirements	*During operation* Fish washing, can seaming, retort process, can cooling Cooling Freezing Fish washing, fish freezing
9. Storage	Decomposition or contamination of product due to poor storage conditions	*During operation of cold store*
10. Final product	Production of product that does not comply with safety, quality, wholesomeness and/or fair trade requirements	*Prior to packaging* On-line inspection Before packaging During storage
11. Recall procedures	Inability to trace product to costumer	*During coding prior to shipping*
12. Employee qualifications	Production of product posing health and safety risks	*Prior to start-up* Retort operators

have occurred in salmon hatcheries. Huss *et al.* (1974) found levels in fish from one trout farm ranging from 340 to 5300 spores/kg. A recent survey of Finnish fish and fishery products for the type E botulism neurotoxin gene using a PCR method found 10–40% positives in raw fish (intestine, surface and whole fish) and 4–14% positive in fish roe (Hyytia *et al.*, 1998). It is clear therefore from these surveys that *Cl. botulinum* will be present in fish and shellfish harvested from salt and freshwater environments and while it may be

possible to prevent extensive contamination by hygienic processing methods, it is not possible to eliminate its presence completely from the raw material.

It is also important to ensure that raw fish intended for cooking or for smoking is stored at temperatures preventing the growth of non-proteolytic *Cl. botulinum* prior to processing. This is usually achieved by chilled storage at very low temperatures (0–2°C) or freezing the fish as shelf life will be short (<6 days) under normal refrigeration conditions (5°C) due to growth of spoilage bacteria. The smoking process for cold-smoked fish products presents a theoretical hazard associated with the potential for growth of proteolytic and non-proteolytic strains of *Cl. botulinum* through exposure of the fish to elevated temperatures for extended time periods (Bell and Kyriakides, 2000).

A number of surveys have been carried out to examine the incidence of *Cl. botulinum* in packaged smoked fish. Heinitz and Johnson (1998) recently found no spores of *Cl. botulinum* in 201 samples of vacuum-packed smoked fish. The greatest hazard to cold-smoked fish products is presented by the growth of *Cl. botulinum* during the refrigerated shelf life. Levels of aqueous salt in excess of 3.5% would readily restrict growth over the normal shelf life of these products (3–4 weeks).

7.17 REFRIGERATED AND FROZEN FISH

For producing high-quality fish products packaged in a modified atmosphere and refrigerated, the following are recommended (Urch, 1997):

1. Use only fresh fish.
2. Ensure that fish temperature is kept below 2°C prior to packing.
3. Pack under cool conditions and move finished pack to chill store as soon as possible.
4. Select appropriate gas mixture suitable for the specific fish.
5. Transport while refrigerated.
6. Keep chilled on arrival.
7. Store at 0–2°C in display cabinets (or chill store).
8. Ensure 'sell by' and 'use by' dates are within achievable limits for that particular product (Garthwaite, 1992).
9. White fish should be in ice for 1–4 days and free from blowfly and parasites.
10. Herring and mackerel should be in ice for 1–3 days and with a minimum fat content of 8%, and salmon and trout should be on ice for 1–3 days.

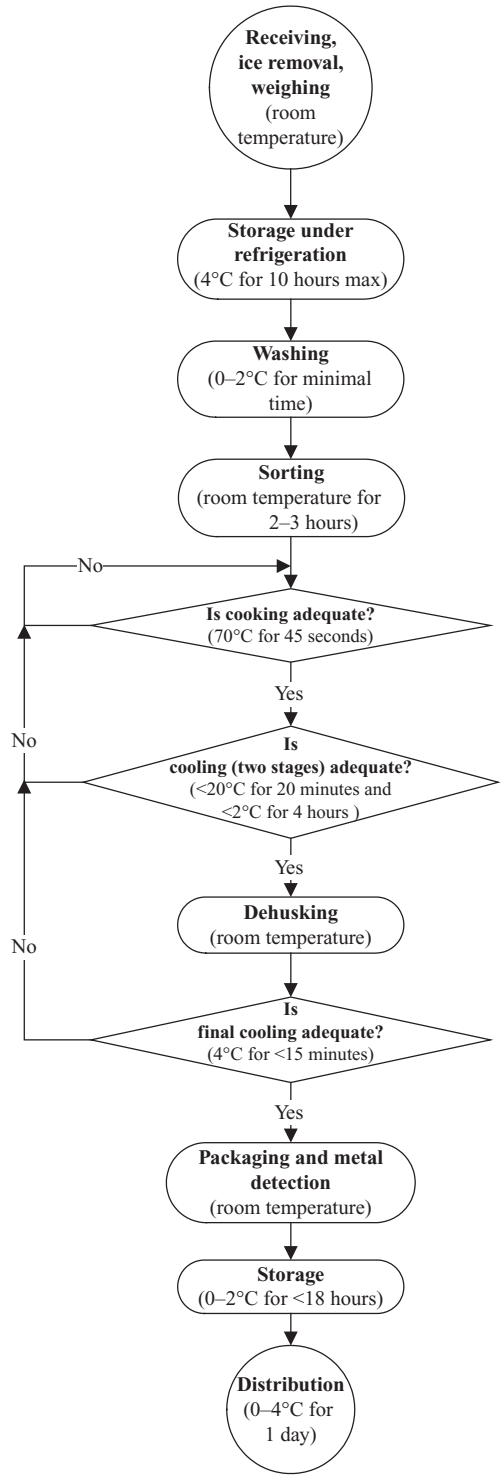

Fig. 7.8 Flow diagram for processing of ready-to-eat dehusked prawns.

Table 7.27 Questions used to determine a CCP for processing of ready-to-eat dehusked prawns according to HACCP analysis.

Processing step	Determination of hazards	Do preventative control measures exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable level(s)?	Will a subsequent step eliminate identified hazard(s) or reduce likely occurrence to acceptable levels?	Is this step a critical control point?
Receiving, ice removal, weighing	Biological: Pathogenic micro-organisms (*Salmonella*, *Shigella* and *Vibrio* spp.), parasites	No	No	No	Yes	
	Chemical: Heavy metals, pesticide residues	No	No	No	Yes	
	Physical: Extrinsic deformations, bruises	No	No	No	Yes	
Storage under refrigeration	Biological: Pathogenic micro-organisms	Yes	No	Yes	Yes	CCP1
	Chemical: Residues	Yes	No	Yes	Yes	
	Physical: Foreign matter	Yes	No	Yes	Yes	
Washing	Biological: Water infected with pathogenic micro-organisms	No	No	No	Yes	
	Chemical: No identified hazard	No	No	No	Yes	
	Physical: No identified hazard	No	No	No	Yes	
Cooking	Biological: Microbial infection, parasites	Yes	No	Yes	Yes	CCP2
	Chemical: Chemical contamination	Yes	No	Yes	Yes	
	Physical: Foreign matter	Yes	No	Yes	Yes	
Cooling	Biological: Water infected with pathogenic micro-organisms	Yes	No	Yes	Yes	CCP3
	Chemical: Infectious agents in water	Yes	No	Yes	Yes	
	Physical: No identified hazards	Yes	No	Yes	Yes	
Dehusking	Biological: Microbial contamination	No	No	No	Yes	
	Chemical: Heavy metals	No	No	No	Yes	
	Physical: Non-potable water	No	No	No	Yes	
Final cooling	Biological: Pathogenic micro-organisms	Yes	No	Yes	Yes	CCP4
	Chemical: Chemical residues	Yes	No	Yes	Yes	
	Physical: Foreign matter	Yes	No	Yes	Yes	

Table 7.27 (Continued)

Processing step	Determination of hazards	Do preventative control measures exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable level(s)?	Will a subsequent step eliminate identified hazard(s) or reduce likely occurrence to acceptable levels?	Is this step a critical control point?
Packaging, metal detection	Biological: Microbial contamination, parasites	Yes	No	Yes	Yes	CCP5
	Chemical: Chemical contamination	Yes	No	Yes	Yes	
	Physical: No identified hazard	Yes	No	Yes	Yes	
Storage	Biological: Growth of pathogenic micro-organisms	Yes	No	Yes	No	CCP6
	Chemical: Chemical contamination	Yes	No	Yes	No	
	Physical: Foreign matter	Yes	No	Yes	No	
Distribution	Biological: Microbial growth and contamination	Yes	No	Yes	No	CCP7
	Chemical: Chemical contamination	Yes	No	Yes	No	
	Physical: Product destruction	Yes	No	Yes	No	

Table 7.28 ISO 22000 analysis worksheet for the determination of prerequisite programmes for processing of ready-to-eat dehusked prawns.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Ice removal, weighing	Yes	Yes	No	Yes	Yes
Storage under refrigeration	Yes	Yes	No	No	No
Washing	Yes	Yes	No	Yes	Yes
Cooking	Yes	Yes	No	No	No
Cooling	Yes	Yes	No	No	No
Dehusking	Yes	Yes	No	Yes	Yes
Final cooling	Yes	Yes	No	No	No
Packaging, metal detection	Yes	Yes	No	No	No
Storage	Yes	Yes	No	No	No
Distribution	Yes	Yes	No	No	No

Table 7.29 Concise HACCP plan for ready-to-eat dehusked prawns.

CCP	Processing step	Hazard	Control measure	Critical limits		Monitoring procedure			Corrective action	Verification procedure
				Target	Tolerance	What	When	Who		
CCP2	Cooking	Survival of sporeformers (pathogenic micro-organisms)	70°C for 45 seconds at the cooling point	80°C at the cooling point	75°C	Time and temperature sheets for cooking	At every lot	Production supervisor	If $T < 75$°C, stay at the cooker until $T = 80$°C	Sporadic control of the efficiency of cooking by microbiological analysis
CCP3	Cooling	Contamination by pathogenic micro-organisms	Filtration and sterilisation by UV of chilled water (0–2°C)	Turbidity analysis negative Security alert in case of UV breakdown	Turbidity analysis 10% out of specs and swab test, level 1 at 10 minutes and level 2 at 60 minutes. No dysfunctioning of security system	Filter control through turbidity measurements and plug analysis for presence of proteins Operation control of UV security system	Every hour Every hour	Production supervisor	Replacement of recycled water with running chlorinated water. Product hold and instructions for recycling or rejection	Effectiveness control of filtration and sterilisation by chemical and microbiological analysis
CCP4	Final cooling	Growth of pathogens, production of toxin from *S. aureus*	Maximum allowed time between cooling and final cooling (final cooling at < 4°C) 60 seconds	30 minutes for filling of every basket during dehusking	45 minutes for filling of every basket	Time recording between the filling of baskets for every worker	During every shift	Production supervisor	In case of delays beyond critical limits product hold and instructions for recycling or rejection	Microbiological analysis for *S. aureus*
CCP5	Packaging and storage	*Listeria* contamination from the air (cooling units) and contact surfaces	Cleaning/ disinfection. No high-pressure water	Absence of *Listeria* in 25 g of sample Swab testing	Swab testing should show level 1 after 10 minutes and level 2 after an hour	Recording of cleaning of surfaces and equipment Recording of swab test analysis	Every time cleaning takes place	Production supervisor	If there is doubt for effectiveness of surface cleaning, swab testing is carried out. If result is unsatisfactory, the process is repeated or cleaning programme is modified	Effectiveness control using swab tests by microbiological analysis TPC on surface <1000/dm^2

Table 7.30 Comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with PRP for ready-to-eat dehusked prawns.

Process step	HACCP CCPs	Prerequisite programme according to ISO 22000?	ISO 22000 CCPs
Ice removal, weighing		Yes	
Storage under refrigeration	1	No	1
Washing		Yes	
Cooking	2	No	2
Cooling	3	No	3
Dehusking		Yes	
Final cooling	4	No	
Packaging, metal detection	5	No	
Storage	6	No	4
Distribution	7	No	

A potential risk in case of modified atmosphere packaging (MAP) of fish is the incidence of growth and toxin production by non-proteolytic types of *Cl. botulinum*, which are widely distributed in aquatic and marine environments and are able to grow at 3.3°C, while the organoleptic attributes of fish are not excessively altered. Modified atmosphere-packaged fillets present increasing trimethylamine content with decrease of temperature (Reddy *et al*., 1997).

For refrigerated and frozen fish/fisheries, it is necessary that the following precautions are taken:

1. Upon receipt of raw material employees should never leave foods at room temperature for hours.
2. For refrigerated storage the upper limit is 3.3°C, and labelling should take place carefully.
3. Thawing should be properly and thoroughly carried out, so that cooking can sufficiently lower the microbial population even at the centre of each food portion.
4. The dimensions of the containers and the thermal properties of these containers should be taken into account for the cooling process.
5. Any contact of refrigerated displayed food with bare hands is not allowed, while the temperature should be kept continuously at or below 3.3°C (Price, 1995).
6. Frozen seafood should be stored at or below −20°C (Hsing-Chen Chen, 1995).
7. For fish due to be chilled, the amount of chlorine in washing water should be under control, otherwise off-flavours may develop. Though washing removes visible blood and dirt, no significant reduction of bacteria number occurs (Huss, 1997b).
8. During shipping, skinless fillets should be neatly wrapped and stored at −10°C or lower; frozen products and master cartons should be in good condition upon loading; and the frozen product should not remain at the loading platform more than 15 minutes (Bonnell, 1994).

Of all the ways to chill fish, ice is the most suitable for the following reasons: (a) it reduces the temperature, (b) melting ice keeps fish moist, (c) ice has a large cooling capacity, (d) ice melting is a self-contained temperature control system, (e) it is a portable cooling method, (f) raw material to produce ice is abundant, (g) ice can be relatively cheap, (h) ice is a safe food-grade substance and (i) ice extends shelf life. The ice should be produced mechanically because this requires less space than the storage of ice brought in from other centres and held until required (Lupin, 1995).

The flow diagram of HACCP implementation in frozen fish steak is shown in Fig. 7.10 and the frozen fish specifications are given in Table 7.35. The questions to determine a CCP for frozen fish according to HACCP analysis are given in Table 7.36. The ISO 22000 analysis worksheet for determination of some PRPs for frozen fish is summarised in Table 7.37 and the comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with PRPs is displayed in Table 7.38.

7.18 SMOKED AND CURED SEAFOOD

Light and vacuum-packed fish such as smoked mackerel, kippers, or sliced smoked salmon constitute semi-preserved items. Fully shelf-stable fishery products including smoked buckling (formation of mastic due to smoking process) can be obtained by applying the microbiological composition assurance (MCA) criteria (Mossel *et al*., 1995). In essence, MCA studies the effect of compositional modification of food on health

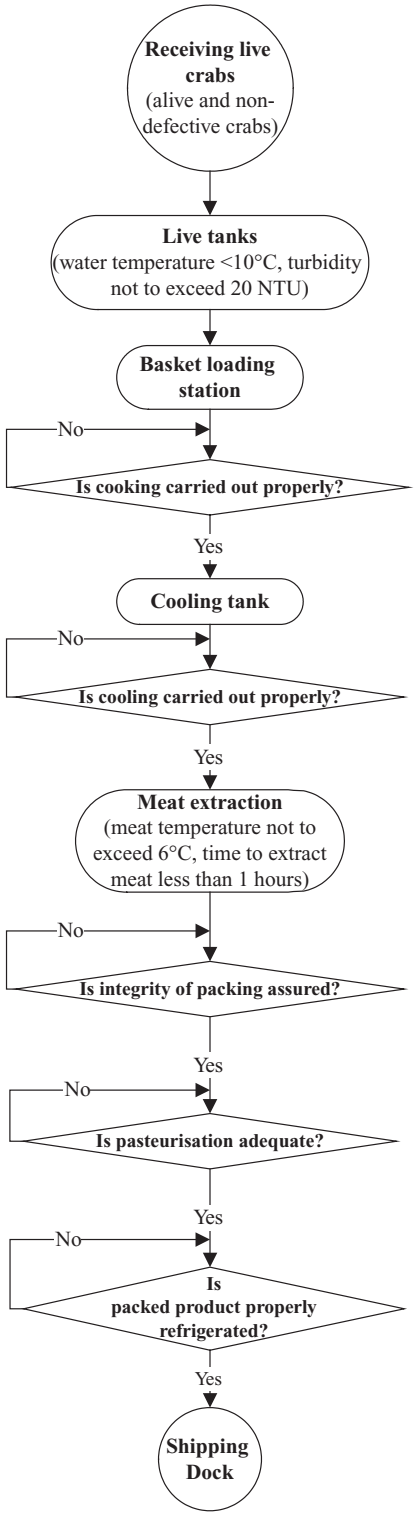

Fig. 7.9 Flow diagram for cooked crabs.

Table 7.31 Cooked crab specifications.

Firm name	ABC Crab Co.
Firm address	Anywhere, USA
Product description	Pasteurised crabmeat in hermetically sealed steel cans
Storage and distribution	Refrigerated
Intended use and consumer	Ready to eat without further processing

significant micro-organisms and adjusting parameters such as a_w, pH and concentration of antimicrobial compounds (Smittle, 1992). The microbial stability in smoked and cured fish can be influenced by the salt level reached after brining, the amount of heat applied (for hot-smoked fish), the inhibitory action of some smoke components and the dehydrating effect of the hot-smoking procedure. The main microbiological hazards in these products are *Cl. botulinum* and *S. aureus*. To eliminate the first one, an adequate heat process is required, for example a minimum internal temperature of 65.5°C for 30 minutes, while *Listeria*, *Salmonella* and *Staphylococcus* are also destroyed (Dodds *et al*., 1992).

Vacuum or modified atmosphere packaging of smoked fish should be limited to products that are frozen, contain sodium nitrite, or are heat-processed so that spores of non-proteolytic *Cl. botulinum* types B, E and F are eliminated (Corby, 1989). Fig. 7.11 shows the flow diagram of hot-smoked and cured fish. CCPs include receiving, splitting, cleaning, unhanging and packaging. Adequate hygiene in a food factory includes the following measures: (a) exclusion of insects; (b) assurance of the bacteriological quality of the water and air supply; (c) adequate cleaning and disinfection of machinery, utensils, conveyor belts, walls and floors; (d) protection of processed fish/seafood (but not yet packed) against contact with condensed water, raw materials, returned goods and containers; (e) avoidance of contact between hands and fish/seafood; (f) absence of pathogens in the packaging material; and (g) control of seal integrity cans and pouches (Kopanic *et al*., 1994). Refrigeration at 4°C is also recommended (Dodds *et al*., 1992). Smoking fish does not seem to inactivate *Listeria* spp. (Hartemink and Georgsson, 1991). It is important to prevent the contamination of smoked fish with *L. monocytogenes*, because even though it can be eliminated during hot smoking there is the possibility of recontamination. On the other hand, it can survive both brining and cold smoking. The solution to this problem is correct

Table 7.32 Questions used to determine CCPs for production of cooked crabs according to HACCP analysis.

Processing step	Determination of hazards	Do preventative control measures exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable level(s)?	Will a subsequent step eliminate identified hazard(s) or reduce likely occurrence to acceptable levels?	Is this step a critical control point?
Receiving live crabs	Biological: Pathogenic micro-organisms, parasites	Yes	No	—	—	
	Chemical: Heavy metals, pesticide residues	Yes	No	Yes	No	
	Physical: No identified hazard	Yes	No	Yes	No	
Live tanks	Biological: Pathogenic micro-organisms, parasites	No	No	No	Yes	
	Chemical: No identified hazard	No	No	No	Yes	
	Physical: No identified hazard	No	No	No	Yes	
Basket loading station	Biological: Microbial contamination	Yes	No	Yes	No	
	Chemical: No identified hazard	No	No	No	Yes	
	Physical: Foreign materials	Yes	No	Yes	No	
Cooking	Biological: Microbial infection, parasites	Yes	No	Yes	No	
	Chemical: No identified hazard	Yes	No	Yes	Yes	
	Physical: Foreign matter	Yes	No	Yes	Yes	
Cooling tank	Biological: Infected with pathogenic micro-organisms	Yes	Yes	—	—	
	Chemical: No identified hazard	Yes	Yes	—	—	
	Physical: No identified hazard	Yes	Yes	—	—	
Cooling	Biological: Microbial contamination	Yes	Yes	—	—	
	Chemical: No identified hazard	Yes	Yes	—	—	
	Physical: No identified hazard	Yes	Yes	—	—	
Meat extraction	Biological: Microbial contamination	Yes	Yes	—	—	
	Chemical: No identified hazard	Yes	Yes	—	—	
	Physical: Foreign matter	Yes	Yes	—	—	
Packing	Biological: Microbial contamination	Yes	No	No	—	CCP1
	Chemical: Chemical contamination	Yes	No	No	—	
	Physical: Foreign matter	Yes	No	No	Yes	

(*Continues*)

Table 7.32 (*Continued*)

Processing step	Determination of hazards	Do preventative control measures exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable level(s)?	Will a subsequent step eliminate identified hazard(s) or reduce likely occurrence to acceptable levels?	Is this step a critical control point?
Refrigerated storage	Biological: Microbial contamination, parasites	Yes	No	Yes	No	
	Chemical: Chemical contamination	Yes	No	No	No	
	Physical: No identified hazard	Yes	No	No	No	
Pasteurisation	Biological: Microbial contamination, parasites	Yes	No	No	Yes	CCP2
	Chemical: Chemical compounds	Yes	No	No	Yes	
	Physical: No identified hazard	Yes	No	No	Yes	
Packed products refrigerated	Biological: Microbial contamination	No	No	Yes	Yes	CCP3
	Chemical: Chemical compounds	No	No	Yes	Yes	
	Physical: Foreign matter	No	No	No	Yes	
Shipping	Biological: Growth of pathogenic micro-organisms	No	No	No	Yes	
	Chemical: No identified hazard	No	No	No	Yes	
	Physical: No identified hazard	No	No	No	Yes	

handling and storage of the products. Adherence to generally accepted and recognised cleaning and sanitation schedules and an effective cold chain are of great importance. A case of listeriosis in smoked mussels has been reported (Fuchs and Nicolaides, 1994). The hot-smoked and cured fish specifications are summarised in Table 7.39. The questions used to determine a CCP for hot-smoked and cured fish according to HACCP analysis are given in Table 7.40. The ISO 22000 analysis worksheet for determination of some PRPs for hot-smoked and cured fish is summarised in Table 7.41 and the comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with PRPs is given in Table 7.42.

7.19 SURIMI

The surimi industry has changed dramatically since 2000. A decrease in Alaskan pollock harvests, from over 6.5 MMT in the late 1980s to less than 3 MMT since the year 2000, has opened the door for the utilisation of new species in the surimi industry. Southeast Asia initiated the expansion by utilising threadfin bream to make surimi, which now represents 25% of the total volume of surimi production. The global decrease in white fish supply has strengthened the demand for other product forms (fillets and blocks) made from Alaska pollock, while the surimi seafood industry has learned to use lower-quality surimi (lower gel

Table 7.33 ISO 22000 analysis worksheet for determination of some prerequisite programmes for cooked crabs.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Receiving live crabs	Yes	Yes	No	Yes	Yes
Live tanks	Yes	Yes	No	Yes	Yes
Basket loading station	Yes	Yes	No	Yes	Yes
Cooking	Yes	Yes	No	Yes	Yes
Cooling tank	Yes	Yes	No	Yes	Yes
Cooling	Yes	Yes	No	Yes	Yes
Meat extraction	Yes	Yes	No	Yes	Yes
Packing	Yes	Yes	No	No	No
Refrigerated storage	Yes	Yes	No	Yes	Yes
Pasteurisation	Yes	Yes	No	No	No
Packed products refrigerated	Yes	Yes	No	No	No
Shipping	Yes	Yes	No	Yes	Yes

Table 7.34 Comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with PRP for cooked crabs.

Process step	HACCP CCPs	Prerequisite programme according to ISO 22000?	ISO 22000 CCPs
Receiving live crabs		Yes	
Live tanks		Yes	
Basket loading station		Yes	
Cooking		Yes	
Cooling tank		Yes	
Cooling		Yes	
Meat extraction		Yes	
Packing	1	No	1
Refrigerated storage		Yes	
Pasteurisation	2	No	2
Packed products refrigerated	3	No	
Shipping		Yes	

Table 7.35 Frozen fish specifications.

Labelling	Species followed by the word 'frozen'
Special storage conditions	To be maintained at –18°C
Instruction for use	Do not freeze again once thawed
Storage conditions and maximum period of storage	Between 0 and 5°C for 1 day Between –5 and 0°C for 1 week Between 12 and –6°C for 1 month At least at –18°C for up to the best before date

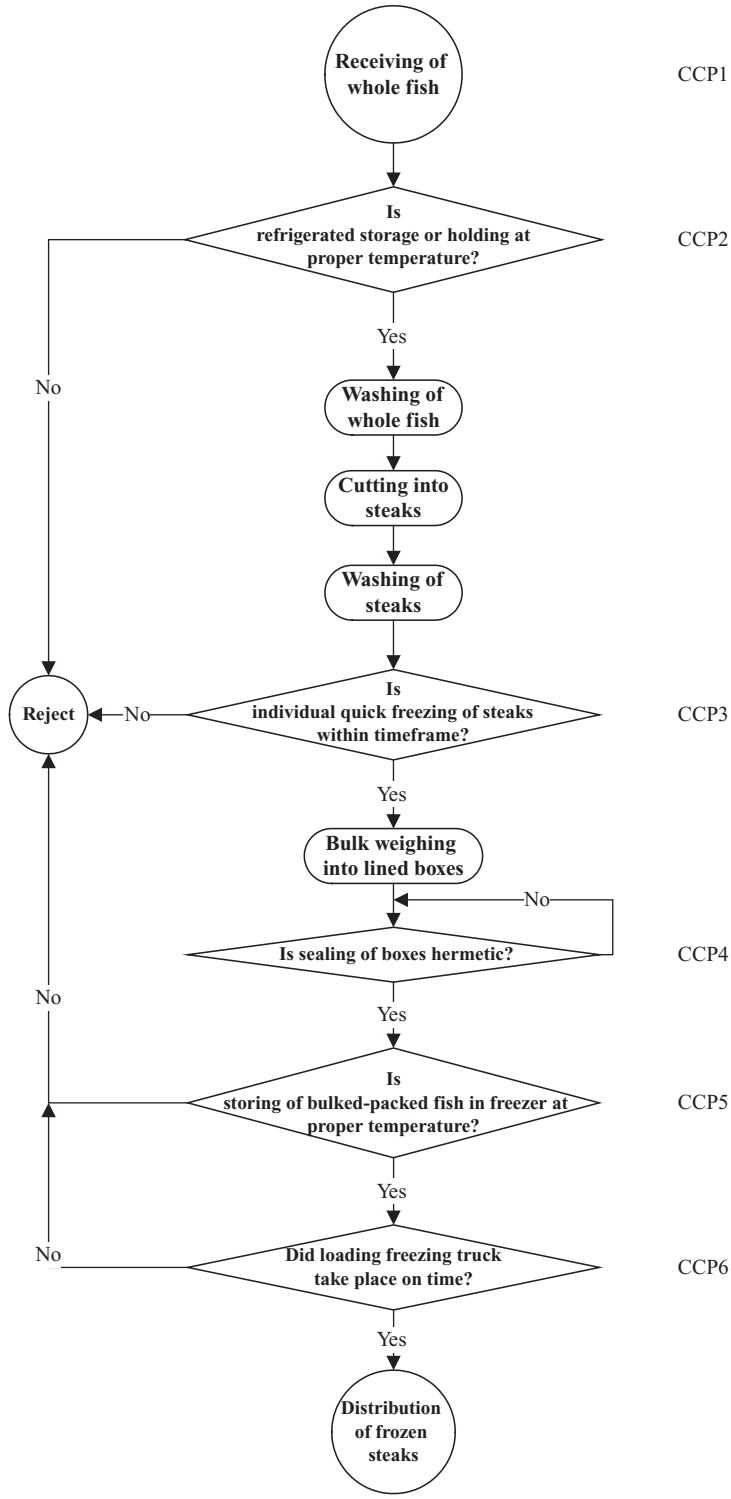

Fig. 7.10 Flow diagram for production of frozen fish steaks.

Table 7.36 Questions used to determine CCPs for production of frozen fish steaks according to HACCP analysis.

Processing step	Determination of hazards	Do preventative control measures exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable level(s)?	Will a subsequent step eliminate identified hazard(s) or reduce likely occurrence to acceptable levels?	Is this step a critical control point?
Receiving of whole fish	Biological: Pathogenic micro-organisms, parasites	Yes	Yes	—	—	CCP1
	Chemical: Heavy metals, pesticide residues, toxins	Yes	No	Yes	No	
	Physical: No identified hazard	Yes	No	Yes	No	
Refrigeration	Biological: Pathogenic micro-organisms growth	Yes	Yes	—	—	CCP2
	Chemical: No identified hazard	No	No	No	Yes	
	Physical: No identified hazard	No	No	No	Yes	
Washing of whole fish	Biological: Pathogenic micro-organisms growth	Yes	No	Yes	No	
	Chemical: No identified hazard	No	No	No	Yes	
	Physical: Foreign materials	Yes	No	Yes	No	
Cutting into steaks	Biological: Cross-contamination	Yes	No	Yes	No	
	Chemical: No identified hazard	Yes	No	Yes	Yes	
	Physical: Foreign matter	Yes	No	Yes	Yes	
Washing of steaks	Biological: Infected with pathogenic micro-organisms	Yes	Yes	—	—	
	Chemical: No identified hazard	Yes	Yes	—	—	
	Physical: No identified hazard	Yes	Yes	—	—	
Individual quick freezing of steaks	Biological: Microbial contamination	Yes	No	Yes	No	CCP3
	Chemical: No identified hazard	Yes	Yes	—	—	
	Physical: Wrong weight	Yes	Yes	—	—	

(*Continues*)

Table 7.36 (*Continued*)

Processing step	Determination of hazards	Do preventative control measures exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable level(s)?	Will a subsequent step eliminate identified hazard(s) or reduce likely occurrence to acceptable levels?	Is this step a critical control point?
Bulk weighing into lined boxes	Biological: No identified hazard	Yes	Yes	—	—	
	Chemical: No identified hazard	Yes	Yes	—	—	
	Physical: Foreign matter	Yes	Yes	—	—	
Sealing boxes	Biological: Microbial contamination	Yes	Yes	—	—	CCP4
	Chemical: Chemical contamination	Yes	No	No	—	
	Physical: No identified hazard	Yes	No	No	Yes	
Storing	Biological: Microbial contamination, parasites	Yes	No	Yes	No	CCP5
	Chemical: Chemical contamination	Yes	No	No	No	
	Physical: No identified hazard	Yes	No	No	No	
Loading freezer truck	Biological: Microbial contamination, parasites due to temperature abuse	Yes	No	Yes	No	CCP6
	Chemical: No identified hazard	Yes	No	No	Yes	
	Physical: No identified hazard	Yes	No	No	Yes	
Distribution of frozen steaks	Biological: Microbial contamination due to temperature abuse	Yes	No	Yes	Yes	
	Chemical: No identified hazard	Yes	No	Yes	Yes	
	Physical: No identified hazard	Yes	No	No	Yes	

Table 7.37 Steaks ISO 22000 analysis worksheet for determination of some prerequisite programmes for production of frozen fish.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Receiving of whole fish	Yes	Yes	No	Yes	Yes
Refrigeration	Yes	Yes	No	Yes	Yes
Washing of whole fish	Yes	Yes	No	Yes	Yes
Cutting into steaks	Yes	Yes	No	Yes	Yes
Washing of steaks	Yes	Yes	No	Yes	Yes
Individual quick freezing of steaks	Yes	Yes	No	Yes	Yes
Bulk weighing into lined boxes	Yes	Yes	No	No	No
Sealing boxes	Yes	Yes	No	No	No
Storing	Yes	Yes	No	Yes	Yes
Loading freezer truck	Yes	Yes	No	No	No
Distribution of frozen steaks	Yes	Yes	No	No	No

functionality and darker colour) to process surimi products from other species (Guenneugues and Morrissey, 2005). The flow diagram of surimi production is shown in Fig. 7.12. Mixing surimi with salt, starch and flavourings enhances many microbiological hazards. To inactivate non-spore-forming bacteria, adequate thermal processing is required, while it is suggested that the core temperature should be $\geq 65^{\circ}$C for at least 3 minutes (Hsing-Chen Chen, 1995). Other common additives might be $NaHSO_3$, cysteine and ascorbic acid (Jiang *et al*., 1998).

Fresh fish are preferred for surimi as they contain less blood and gut residues in the tissues and experience less autolysis of the muscle proteins giving a better gel. A uniform size of fish is important for consistent yields from deboning/mincing machines, and

Table 7.38 Comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with PRP for production of frozen fish.

Process step	HACCP CCPs	Prerequisite programme according to ISO 22000?	ISO 22000 CCPs
Receiving of whole fish	1	Yes	
Refrigeration	2	Yes	
Washing of whole fish		Yes	
Cutting into steaks		Yes	
Washing of steaks		Yes	
Individual quick freezing of steaks	3	Yes	
Bulk weighing into lined boxes		No	
Sealing boxes	4	No	1
Storing	5	Yes	
Loading freezer truck	6	No	2
Distribution of frozen steaks		No	

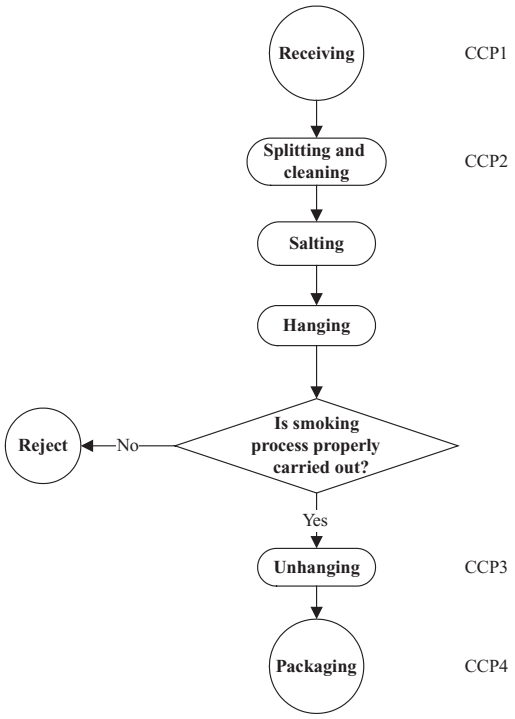

Fig. 7.11 Flow diagram of hot-smoked and cured fish.

fish with a good flesh to frame ratio may give overall better yields of mince. Water quality is important for preventing microbial growth. Salt is added to lower the water activity, but its concentration should be >0.2%, otherwise actin and myosin may be solubilised. The surimi must be stored below 20°C (Hall and Ahmed, 1992).

The gel properties of surimi from pollock, Pacific herring, arrowtooth flounder, and Pacific whiting as affected by its moisture content can be evaluated by measuring torsion stress and strain, applying punch test and measuring L*, a* and b* values of colour of surimi (Reppond and Babbitt, 1997). Other applications of thermostable water dispersions of fish meat may include spray-dried protein powders, fish sauces and biofilms (Venugopal, 1997).

It has recently been demonstrated that all the muscle fibre proteins in cod and several other white-fleshed species, as well as mackerel light muscle, can be almost completely extracted in solutions of physiological ionic strength, 150 mM, or less (Stefansson and Hultin, 1994). With white-fleshed species, it is only necessary to wash the samples and extract in a sufficient volume of water to reduce the ionic strength to less than 0.3 mM. In the case of mackerel light muscle, however, muscle tissue has to be first washed with a neutral solution of moderate ionic strength. This removes some proteins, which then allows the remaining myofibrillar proteins, including myosin, to become extractable in the low ionic strength solution (Hultin *et al*., 2005).

The addition of alkali in the surimi wash water produces a higher-quality product than just using water. Various concentrations of sodium bicarbonate can be added in one or more of the wash steps to increase the pH. Sodium chloride is also added sometimes. It has been suggested that gelation is improved after this type of washing process because the 'solubility of the sarcoplasmic proteins increased and there is a 'decreased rate of denaturation as the muscle pH increased' (Shimizu *et al*., 1992).

It is generally accepted that it is 'impossible to make surimi from small pelagic species that are not fresh' (Suzuki and Watabe, 1987). Development of fishy and rancid odours from lipid oxidation is a serious problem in processing dark-muscled fish into surimi (Shimizu *et al*., 1992), but these odours can be reduced with early antioxidative intervention. Surimi from light mackerel muscle lost no sensory quality after 1 year of storage at −20°C and only about 10% of its true strain value when there was early treatment with antioxidants (Kelleher *et al*., 1994).

Myoglobin is present at high concentrations in dark muscle but there is very little present in fish light muscle. Although it is widely reported that haemoglobin

Table 7.39 Hot-smoked and cured fish specifications.

Firm name	Hot Smoked Fish Company, Inc.
Firm address	USA
Product description	Refrigerated, vacuum-packaged, cooked ready-to-eat smoked fish (no mercury-containing species used
Storage and distribution	Stored and transported under refrigeration
Intended use and consumer	Ready to eat by general public without further cooking

Table 7.40 Questions used to determine CCPs of hot-smoked and cured fish according to HACCP analysis.

Processing step	Determination of hazards	Do preventative control measures exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable level(s)?	Will a subsequent step eliminate identified hazard(s) or reduce likely occurrence to acceptable levels?	Is this step a critical control point?
Receiving of fish	Biological: Pathogenic micro-organisms, parasites	Yes	Yes	—	—	CCP1
	Chemical: Heavy metals, pesticide residues, toxins	Yes	No	Yes	No	
	Physical: No identified hazard	Yes	No	Yes	No	
Splitting and cleaning	Biological: Pathogenic micro-organisms growth	Yes	Yes	—	—	CCP2
	Chemical: No identified hazard	No	No	No	Yes	
	Physical: No potable water	No	No	No	Yes	
Salting	Biological: Pathogenic micro-organisms growth	Yes	No	Yes	No	
	Chemical: No identified hazard	No	No	No	Yes	
	Physical: Foreign materials	Yes	No	Yes	No	
Hanging	Biological: Cross-contamination	Yes	No	Yes	No	
	Chemical: No identified hazard	Yes	No	Yes	Yes	
	Physical: Foreign matter	Yes	No	Yes	Yes	
Smoking	Biological: Infected with pathogenic micro-organisms	Yes	Yes	—	—	
	Chemical: No identified hazard	Yes	Yes	—	—	
	Physical: No identified hazard	Yes	Yes	—	—	
Unhanging	Biological: Microbial contamination	Yes	No	Yes	No	CCP3
	Chemical: Chemical contamination	Yes	Yes	—	—	
	Physical: No identified hazard	Yes	Yes	—	—	
Packaging	Biological: Micro-organisms growth	Yes	Yes	—	—	CCP4
	Chemical: Chemical contamination	Yes	Yes	—	—	
	Physical: Foreign matter	Yes	Yes	—	—	

Table 7.41 ISO 22000 analysis worksheet for determination of some prerequisite programmes for hot-smoked and cured fish.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Receiving of fish	Yes	Yes	No	No	No
Splitting and cleaning	Yes	Yes	No	No	No
Salting	Yes	Yes	No	Yes	Yes
Hanging	Yes	Yes	No	Yes	Yes
Smoking	Yes	Yes	No	Yes	Yes
Unhanging	Yes	Yes	No	No	No
Packaging	Yes	Yes	No	No	No

is less susceptible to oxidation than myoglobin, this is only true of the tetrameric form of haemoglobin (Shikama and Matsuoka, 2003).

Until now, there has been no entirely satisfactory way of mechanically removing the head and abdominal cavity contents. Some interesting approaches to this problem were discussed by Langmyhr *et al.* (1988). These techniques have included putting fish on conveyer belts under pressure to squeeze out the intestines and roe. This, however, would not remove the head. Another method involves washing pieces of capelin for 45 minutes in weak acid at 20°C or at neutral pH at 40°C (Eide *et al.*, 1982).

Surimi seafoods are often vacuumed packed and sold under refrigerated storage. The potential hazards for surimi seafood can include the inclusion of metal fragments and the existence of human pathogens, such as *L. monocytogenes* and *Cl. botulinum*. Therefore, CCPs for eliminating or reducing these hazards from surimi seafood include the pasteurisation

Table 7.42 Comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with PRP for hot-smoked and cured fish.

Process step	HACCP CCPs	Prerequisite programme according to ISO 22000?	ISO 22000 CCPs
Receiving of fish	1	No	
Splitting and cleaning	2	No	1
Salting		Yes	
Hanging		Yes	
Smoking		Yes	
Unhanging	3	No	
Packaging	4	No	2

Table 7.43 Surimi description.

Aquatic product raw material	Pacific whiting (*Merluccius* spp.), pollock (*Theragra chalcogramma*)
Raw material harvest area	Off Oregon coast
Raw material received	Directly from harvester
Finished product	Frozen surimi
Food additives, ingredients, processing aids	Sorbitol, sugar, polyphosphate, protease inhibitor, water
Shipping	Shipped in the firm's refrigerated trucks
Intended use	Raw material for fully cooked imitation seafood products
Intended consumers	General public

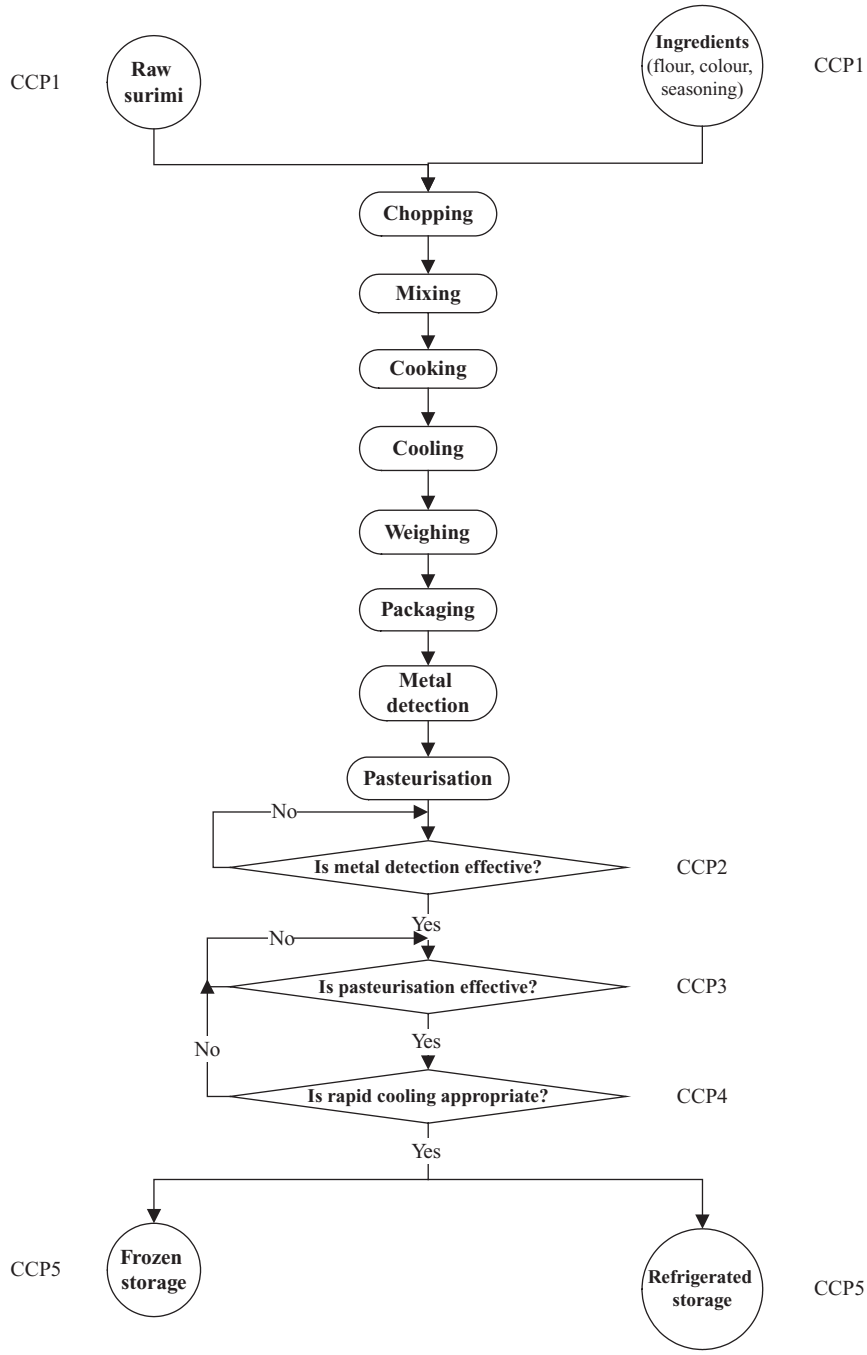

Fig. 7.12 Flow diagram of surimi seafood production.

Table 7.44 Questions used to determine CCPs for surimi seafood production according to HACCP analysis.

Processing step	Determination of hazards	Do preventative control measures exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable level(s)?	Will a subsequent step eliminate identified hazard(s) or reduce likely occurrence to acceptable levels?	Is this step a critical control point?
Raw surimi	Biological: Pathogenic micro-organisms, parasites	Yes	Yes	—	—	CCP1
	Chemical: Pesticide residues, toxins	Yes	No	Yes	No	
	Physical: No identified hazard	Yes	No	Yes	No	
Chopping	Biological: Pathogenic micro-organisms growth	Yes	Yes	—	—	
	Chemical: No identified hazard	No	No	No	Yes	
	Physical: Foreign matter	No	No	No	Yes	
Mixing	Biological: Micro-organisms survival	Yes	No	Yes	No	
	Chemical: Chemical contamination	No	No	No	Yes	
	Physical: Foreign materials	Yes	No	Yes	No	
Cooking	Biological: Micro-organisms growth	Yes	No	Yes	No	
	Chemical: No identified hazard	Yes	No	Yes	Yes	
	Physical: Foreign matter	Yes	No	Yes	Yes	
Cooling	Biological: Infected with pathogenic micro-organisms	Yes	Yes	—	—	
	Chemical: No identified hazard	Yes	Yes	—	—	
	Physical: No identified hazard	Yes	Yes	—	—	
Weighing	Biological: Microbial contamination	Yes	No	Yes	No	
	Chemical: No identified hazard	Yes	Yes	—	—	
	Physical: Wrong weight	Yes	Yes	—	—	

Table 7.44 (*Continued*)

Processing step	Determination of hazards	Do preventative control measures exist?	Is the step specifically designed to eliminate or reduce the likely occurrence of hazard to an acceptable level?	Could contamination with identified hazard(s) occur in excess of acceptable level(s) or could these increase to acceptable level(s)?	Will a subsequent step eliminate identified hazard(s) or reduce likely occurrence to acceptable levels?	Is this step a critical control point?
Packaging	Biological: No identified hazard	Yes	Yes	—	—	
	Chemical: No identified hazard	Yes	Yes	—	—	
	Physical: No identified hazard	Yes	Yes	—	—	
Metal detection	Biological: No identified hazard	Yes	Yes	—	—	CCP2
	Chemical: Chemical contamination	Yes	No	No	—	
	Physical: No identified hazard	Yes	No	No	Yes	
Pasteurisation	Biological: *Listeria monocytogenes*	Yes	No	Yes	No	CCP3
	Chemical: Chemical contamination	Yes	No	No	No	
	Physical: No identified hazard	Yes	No	No	No	
Rapid cooling	Biological: *Listeria monocytogenes*	Yes	No	Yes	No	CCP4
	Chemical: No identified hazard	Yes	No	No	Yes	
	Physical: No identified hazard	Yes	No	No	Yes	
Frozen/refrigerated storage	Biological: *Listeria monocytogenes*	Yes	No	Yes	Yes	CCP5
	Chemical: No identified hazard	Yes	No	Yes	Yes	
	Physical: No identified hazard	Yes	No	No	Yes	

process, rapid cooling and low-temperature storage and metal detection (Su and Daeschel, 2005).

Pasteurisation is a heat process designed to eliminate targeted bacterial pathogens and reduce total populations of spoilage bacteria in products. Although bacterial spores usually survive the heat process, a properly pasteurised product should contain a minimal amount of spoilage bacteria and be free of pathogens. Rapid cooling of pasteurised products will prevent the germination of bacterial spores and the growth of spore-forming bacteria such as *Bacillus* and *Clostridium* species. Pasteurised surimi seafood should be cooled from 60°C to less than 21.1°C within two hours and to less than 4.4°C within another four hours to prevent spore germination as well as retard the growth of spoilage bacteria (Himelbloom *et al.*, 2000). Vacuum-packed surimi seafoods that are sold under refrigerated storage should be kept at temperatures below 3°C to prevent the growth and toxin production of non-proteolytic types of *Cl. botulinum*. Foreign objects

Table 7.45 ISO 22000 analysis worksheet for determination of some prerequisite programmes for surimi seafood production.

Processing step	Are the technical infrastructure and the preventative maintenance programme adequate?	Is it feasible to evaluate them?	Do they contribute to the control of recognisable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite programme?
Raw surimi	Yes	Yes	No	Yes	Yes
Chopping	Yes	Yes	No	Yes	Yes
Mixing	Yes	Yes	No	Yes	Yes
Cooking	Yes	Yes	No	Yes	Yes
Cooling	Yes	Yes	No	Yes	Yes
Weighing	Yes	Yes	No	Yes	Yes
Packaging	Yes	Yes	No	Yes	Yes
Metal detection	Yes	Yes	No	No	No
Pasteurisation	Yes	Yes	No	No	No
Rapid cooling	Yes	Yes	No	Yes	No
Frozen/refrigerated storage	Yes	Yes	No	No	No

such as metal fragments can cause injury to consumers and should be considered as possible hazards associated with surimi seafood production. Metal fragments can be produced through metal-to-metal contact, especially during mechanical cutting or blending operations during surimi and surimi seafood production (FDA, 2001c). The surimi specifications are summarised in Table 7.43. The questions used to determine a CCP for surimi according to HACCP analysis are given in Table 7.44. The ISO 22000 analysis worksheet for determination of some PRPs for surimi is summarised in Table 7.45 and the comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with PRPs is given in Table 7.46.

7.20 RISK ASSESSMENT

Probably the main development in HACCP food regulations, in the coming years, will be the incorporation of quantitative risk assessment procedures. The concept of risk is germane to HACCP. Risk is a statistical numerical value, the likelihood of occurrence of a given hazard. Therefore the evaluation of the change of the level of risk, associated with a given hazard of a given product, would be the direct verification of the effectiveness of the HACCP system. As in general more than 90% of the recorded food outbreaks are associated with microbiological hazards, risk in this context refers mainly to microbiological risk (Lupin, 1999).

Table 7.46 Comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with PRP for surimi seafood production.

Process step	HACCP CCPs	Prerequisite programme according to ISO 22000?	ISO 22000 CCPs
Raw surimi	1	Yes	
Chopping		Yes	
Mixing		Yes	
Cooking		Yes	
Cooling		Yes	
Weighing		Yes	
Packaging		No	
Metal detection	2	No	1
Pasteurisation	3	Yes	2
Rapid cooling	4	No	3
Frozen/refrigerated storage	5	No	

However, qualitative risk assessment implies a qualitative assessment of a statistical value, something that is open to a large degree of uncertainty, particularly in cases where there is not a clear CCP where the hazard could be controlled. If we have a clear process step where we can practically eliminate the hazard (e.g. retort sterilisation or metal detector), we know that we can reduce the risk. On the other hand, if where there is a hazard such as histamine formation or contamination with *Salmonella* spp., we have a different situation. Since the hazard may occur at many places, and at different times, before, during and after processing, it creates a situation where there is not a clear point where the risk of such a hazard to a negligible value can be reduced. Of course, a number of control measures can be taken, but the risk may continue, in practice, to be relatively high. As has been pointed out qualitative risk assessment cannot address the process's inherent variability in any meaningful manner (Buchanan and Whiting, 1998).

Reducing marine-based public health risk requires strict control for the quality of several attributes of seafood products, including location and conditions of catch or aquaculture, processing and handling throughout the supply chain. These quality assurance activities may be tracked, recorded and communicated through the supply chain via certification documentation for buyers in the chain and through labels or websites for consumer products.

Caswell (2006) discusses the potential for certification and labelling as a mechanism for reducing marine-based public health risks. Several challenges must be met if labelling, particularly consumer labelling, is to support the development of markets for improved seafood safety.

7.21 CONCLUSIONS

Canned seafoods are characterised by a pH > 4.6 and a_w > 0.98. Foods with pH greater than 4.6 are called 'low-acid canned foods' for which the micro-organism of major concern is *Cl. botulinum*. Some strains of *Cl. botulinum* produce spores that are the most heat resistant of all pathogenic micro-organisms. Consequently, the fish canning industry must rely on thermal processes sufficient to ensure the lowest probability of survival of *Cl. botulinum* spores so as to present no significant health risk to consumers (Ababouch, 2002).

Application of the HACCP approach to the control of fishborne parasites should start with assessment of the risk that certain species of fish caught or harvested in endemic areas are infected. The risk of disease should also be determined; this will depend on the specific parasite and whether the possibility of acquiring the infection thorough eating fish is eliminated by cooking or another preparation process before consumption. A risk will exist if fish from endemic areas are consumed raw or inadequately processed (Murrell, 2002).

The following annexes are attached to the HACCP manual to describe the appropriate preventative and monitoring procedures to be implemented:

1. SSOPs (layout, circulation of personnel and products, personnel hygiene, pest control, water supply) and control of SSOP (control of personnel hygiene, of cleaning and sanitation, of water quality and water chlorine level).
2. Standard handling, icing and transportation of fresh fish.
3. Standard sterilisation procedure.
4. Measurement of fish temperature.
5. Sensory evaluation of fresh fish.
6. Determination of total volatile bases.
7. Determination of histamine.
8. Verification of the container closure.
9. Determination of heat penetration and temperature distribution in the retorts.

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8
Catering

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8.1 INTRODUCTION

According to the World Health Organization (WHO), the medical costs and the value of the lives lost from just five foodborne infections in England and Wales were estimated in 1996 at between $300 million (minimum value) and $700 million (maximum value) annually (WHO, 2000). More recently, annual costs to the UK have been estimated as being between $500 million and $1 billion (Joint Food Safety Standards Group, 2000), and the Food Standards Agency had set itself the target of a 20% reduction in the incidence of foodborne disease by 2006 (Griffith *et al.*, 2001).

The relationship between catering establishments and outbreaks of food poisoning, together with growing public awareness, has been of increasing concern to the UK government and a report produced by the Parliamentary Office of Science and Technology (Border and Norton, 1997) stated that 'eating out remains a very important source of food poisoning'. Coleman *et al.* (2000) reported that although consumers may not always adhere to safe practices within the confines of their own home, they do expect the highest quality standards from professionals within the food industry.

The catering industry has undergone many changes over recent years (Coleman, 2000; Coleman and Griffith, 1997), and given that social patterns, travel opportunities and eating habits have also changed, the industry has had to cater for an increasingly diversified customer base and quality-conscious consumer. To fulfil the needs of this growth and diversification, employment within the industry has also grown, increasing fourfold between 1970 and 1990 (Coleman and Roberts, 2005).

The catering industry includes a great number and diversity of food businesses. However, there are several factors such as the poor level of food safety knowledge among staff, the high turnover of staff and businesses and the lack of motivation and incentives which hardly encourage the adoption of the system. The majority of catering businesses has no formal training in food safety management and only a few are represented by trade associations (FSA, 2002).

Function catering is the term used to cover the catering service provided at special functions for specific groups of people at specific times. With regards to the catering requirements, there are two main types of function, the formal meal and the buffet. At formal meals, such as a banquet, wedding breakfast, retirement presentation or conference dinner, all the guests eat food from the same menu or there is a restricted choice of dishes. At buffets, the food can be hot or cold, fork or finger. The food may be served from the buffet or the guests may help themselves. Some events may feature a barbecue where food is cooked during the function. Caterers in hotels may have to service several different functions in one day and continue to service a restaurant for residents and the general public. Seasonal events, such as Christmas parties, can place heavy demands on the caterer's resources as there are many functions to be catered for within a short period of time (Worsfold, 2001).

Restaurants and hotels, the main providers of function catering, were implicated in 39% of general outbreaks of foodborne illness (Phillips *et al.*, 1995). Statistics suggest improper food-handling behaviour may be implicated in 97% of all foodborne illness outbreaks associated with catering establishments (Howes *et al.*, 1996).

At a wedding reception in 1998 attended by 84 people, 34 of the guests developed symptoms of food poisoning within two days. Stool and vomit samples revealed the presence of *Salmonella* (Worsfold, 2001). Environmental health officers investigating the

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outbreak asked staff to recreate the cooking of the turkey breast joint that was served at the buffet. The joint was cooked at the same temperature and for the same length of time, and it was found that the joint was undercooked. Surviving pathogens were thought to have been transferred by the chefs to other products by the use of boards, knives and other kitchen equipment.

Salmonella enteritidis was the pathogen implicated in a food-poisoning outbreak at a Rotary dinner in a three-star hotel in Clevedon, Somerset (Panorama, 1999). The pathogen isolated from 27 guests who fell ill was traced to the dessert, tiramisu, which had been made with raw eggs in advance and had been subjected to inadequate temperature control. The owner, manageress and the chef of the hotel were prosecuted for offences under the Food Safety Act by the North Somerset Consumer Protection Department. The main risk factors associated with general outbreaks of foodborne illnesses in catering establishments are as follows:

- preparation too far in advance
- storage at ambient temperature
- inadequate cooling and reheating (Hobbs and Roberts, 1995).

All of these risk factors may be associated with function catering because of the necessity to cater for large numbers of people simultaneously. This requires considerable advance preparation and cooking followed by cooling, storage and then regeneration. The display and service of high-risk foods at ambient temperatures on buffets is a common feature of function catering (Worsfold, 1986).

Hazard analysis is a legal requirement for all catering businesses, which must apply the principles in the Food Safety (General Food Hygiene) Regulations 1995. Guidance for caterers is provided in publications such as Assured Safe Catering (DoH, 1993), Systematic Assessment of Food Environment (British Hospitality Association, 1995) and the Industry Guide to Good Hygiene Practice (Food Safety and Hygiene Working Group and Department of Health, 1997). Similar guidelines were issued in all European Union (EU) member states by relevant authorities in compliance with Regulation (EC) No. 178/2002.

In the UK, the formal HACCP system used by food manufacturers is a legal requirement and the applicability to catering businesses has been questioned (Ehiri *et al.*, 1995). In addition, there is now greater appreciation of the importance of businesses establishing prerequisite hygiene programmes, including good personal hygiene, sanitation programmes and pest control, prior to the introduction of the HACCP system (Owen-Griffiths, 2001).

Clayton *et al.* (2002) in their recent study of caterers in Wales, identified a number of 'behaviours' and 'actions' that should be carried out, including, for example: (1) washing hands, (2) preventing cross-contamination, (3) ensuring food is cooked (or reheated) quickly, (4) maintaining good standards of personal hygiene, (5) temperature control, (6) keeping raw and cooked foods separate, and (7) making sure that employees are trained.

The provision of food hygiene training for all food handlers, as part of a combined approach to food hygiene management, could help reduce the incidence of foodborne disease anywhere in the world. Traditional approaches to food hygiene control such as legislation, inspections and end-product testing have been found promising and training represents a possible solution, offering long-term and transferable benefits across the food industry. Moreover, food businesses should adopt a risk-based approach to food safety, founded upon the philosophy of the HACCP system (Codex Alimentarius Commission, 1993). The adoption of all seven principles of HACCP is currently a legal requirement for all food businesses (Reg. 852/2004), and the system is internationally recognised as an effective method of food safety management and the best way to control an ever-increasing public health risk from foodborne diseases (Maurice, 1994).

Moreover, Mortlock *et al.* (2000) showed that UK retail and catering businesses lag well behind manufacturers in their use of HACCP and concluded that training would be an important factor in any future strategies to encourage use of the system. Training is important in raising industry awareness about HACCP and ensuring that the potential benefits of HACCP to the food industry, regulatory authorities and ultimately the consumer, are realised (Mayes, 1994).

The food hygiene training received and qualifications held by four different grades of food handlers were compared by means of a postal survey of 1650 businesses in the manufacturing, retail and catering sectors of the UK food industry. Significant differences ($p < 0.05$) were identified by Mortlock *et al.* (2000) between the methods of training delivery to, and qualifications held by different grades of food handlers across the three industry sectors. Business status, personnel characteristics and risk perceptions of managers all had significant effects on the methods of training used and qualification levels achieved within each industry sector. Positive attitudes towards training were expressed by most managers although follow-up

face-to-face interviews revealed their concerns about the cost, time and relevancy of the training their staff received.

The benefits of hygiene training need to be more widely promoted in order to encourage managerial commitment to staff training. Managers must be made aware of the inherent risks involved in their business practices and the contribution training makes to minimising these risks. Further research is essential to develop training methods that are proven to change workplace behaviour, without which the full benefits of training are unlikely to be realised. To achieve this behavioural change, it is important that businesses see training as one part of a broader food hygiene control strategy, based upon the principles of the HACCP system. This would help shift the emphasis of training from certification and knowledge to more risk-based concepts, specific to the working practices of trainees. By incorporating hygiene training within HACCP, businesses would be encouraged to treat training as an ongoing rather than a one-off activity, often carried out purely in response to the requests of local enforcement officers. In the same way that hygiene training is likely to be more effective if guided by the principles that underpin the HACCP system, so too HACCP is likely to be more effective if all staff within a business have the appropriate training. In order to provide the food safety assurances required by consumers in the twenty-first century, it seems clear that the futures of food hygiene training and HACCP remain inextricably linked (Mortlock *et al.*, 2000).

The most common bacteria that cause foodborne diseases in the USA are *Salmonella* (378 incidents in 2003), pathogenic *Escherichia coli* (272 incidents of *E. coli* O157:H7 in 2002 and 74 incidents in 2003), and *Campylobacter* (126 incidents in 1997 and 268 incidents in 2002). Over 325,000 people are hospitalised each year and there are up to 5000 deaths in the USA – mostly children and the elderly (http://www.outbreakinc.com/Resources/). The onset times of sickness and their syndromes are different due to the species involved, the health conditions of hosts, and the amounts of bacteria (can sometimes be less than 100 cfu/g) or toxins consumed.

In the period 1999–2000, 1267 outbreaks of foodborne disease were reported to the French health authorities. The surveillance data showed that *Salmonella* (64%), *Staphylococcus aureus* (16%) and *Clostridium perfringens* (5.1%) were the most commonly identified aetiological agents. As clinical manifestations are common in hospitalised patients, the true incidence of outbreaks of foodborne disease in hospitals and extended-care facilities is not known. It is unlikely that all events are reported. Hospitalised people are more likely than non-hospitalised people to become ill when exposed to foodborne agents. Small numbers of enteric pathogens that may be innocuous to most healthy people can cause disease and even death in highly susceptible patients, especially in immunocompromised subjects. The main factors that contribute to the occurrence of foodborne disease are: keeping food at temperatures outside the recommended range; inadequate cooking; poor personal hygiene among food handlers; use of food from unsafe sources; and use of contaminated equipment. As hospitalised patients are at increased risk of becoming ill when exposed to potential foodborne pathogens, and as hospital food services need to provide a wide variety of dietary items, it is critical that appropriate food-handling practices are maintained (Reglier-Poupet *et al.*, 2005).

Gastrointestinal infections, a growing problem worldwide, can be a major concern if customers or consumers became ill as a result of foods from catering or food service. These types of cases usually involve large numbers of consumers instead of several isolated individuals. The reported foodborne illness cases per year were 76 million in the USA (Tauxe, 2002) and 9.4 million in the UK (Walker *et al.*, 2003). It was also reported in a combined statistics results from the USA, UK and the Netherlands that up to 70% of food illnesses were associated with catering or food service functions (Griffith, 2000) which indicated the importance of food safety in the food service areas.

Food safety is one of the most important aspects in food service operations but usually receives the smallest amount of visibility and attention (Manask, 2002). However, the need to ensure food safety has caused a lot of public concerns. It has been suggested that food should be safe from harmful substances from farm to fork and since food service is the last or almost the last step in the food preparation chain, it guards the final linkage of food safety for the public in the operational food chain. Thus, it is very important to maintain safety of the food that is served by the food service areas (Sun and Ockerman, 2005).

HACCP was established in 1977, and has become the universally accepted method for increasing food safety and has been adopted for food assurance in many food areas (Griffith, 2000). However, due to the complexity of foods, and the preparations involved in food service, it is harder to monitor and control the food safety in this segment of the industry. The structures and the varieties (the locations, on the street or stores; the various sizes; the type of foods that they serve) in several food service areas are the factors that

make food service unique and different from food manufacturing. It is much more difficult for a small enterprise to apply HACCP than for a large one because of different work facilities and demands. Several researches had concluded that improper food handling and/or storage techniques need to be improved and changed, in order to decrease foods that caused illnesses (Manask, 2002). This can be accomplished by education and applications of HACCP which has proved to be the best method to achieve this goal.

Research shows that education with knowledge of food safety and proper food handling are needed and will help the food service personnel (workers and managers) to a better understanding in food service and better hygiene practices which results in safer foods. Besides risk assessment, HACCP has been applied in most of the food production areas (Sun and Ockerman, 2005). For most of the food chain, HACCP is mandatory by law and government regulations. There appears to be a need to apply prerequisite programmes (PRPs; Seward, 2000; Walker *et al*., 2003) and later HACCP in food service areas to ensure the safety of food consumption in the total food chain (Panisello and Quantick, 2001) since a chain is no stronger than its weakest link.

Hazards that have little or no risk, or are unlikely to occur, can often be monitored and controlled by standard operation procedures (SOPs; routine employee hygiene practices, cleaning procedures etc.) and good manufacture practices (GMPs) and it may not be necessary to use the CCPs addressed by the HACCP system (McSwane *et al*., 2003). But significant hazards that might occur during processing will need to be monitored and addressed as CCPs.

Food service contains more hazards mainly due to the time and procedures involved from the preparation of food to serving of the food. The handling and assembling, holding time and temperature, reheating procedures and serving hygiene of personnel are all factors that make food service operations unique and different from food manufacturing. Large food service units can be big restaurants, hotels, nursing homes, schools and hospital cafeterias, health-care centres, etc., that serve a wide variety of food to hundreds of people at meal times; and smaller units such as cafés, snack or sandwich bars, coffee bars, kiosks, carts etc. (Manask, 2002) which serve a limited variety of food to less people.

Proper kitchen layout and flow charts of food production are the first two things that need to be considered before implementation of HACCP in food service. Kitchen design and operation according to HACCP concepts (Hopkins, 1991) will help in HACCP implementation and applications. Kitchen layout must support physical segregation during storage and preparation with one-way flow of the food processing after hygienic facilities are established.

The most commonly used CCPs in kitchen operations are cooking, cooling, reheating and hot/cold holding (McSwane *et al*., 2003). HACCP programmes need to be established for each food product preparation and this should contain the flow chart as well as SOPs that need to be accomplished (e.g. receiving, storage, cooking, serving etc.), type of hazards (physical, chemical or biological), control methods, control limits, monitoring frequency and documentation, corrective actions when limits are exceeded and the personnel who are responsible (Seward, 2000; Soriano *et al*., 2002b).

Soriano *et al*. (2002b) also provided detailed examples of processing flow charts and HACCP worksheets for two cooked food items. In the worksheets of HACCP, details such as what type of food is prepared in the kitchen (ready to eat – RTE, ready to use – RTU etc.) and how the storage conditions are before and after cooking are recorded before HACCP implementation in food service (Bryan, 1981).

Moreover, the environment is very important when consuming food. Meiselman (2003) described the importance of the context or environment in judgements of product quality and assessments of product acceptability. He reviewed the growth of the three-factor approach to understanding quality and acceptability, and presented an example of current research in each. Meal context, expectations and eating location research are reviewed as examples of the three-factor approach.

Of foodborne outbreaks, 66% in England and Wales (WHO, 2000), almost 48% in Mexico (Parrilla-Cerrilo *et al*., 1993) and 86% in Egypt (Fawzi, 1999) are attributed to *S. aureus*. Staphylococci account for an estimated 5, 8, 10, 30, 15 and 24% of the total of foodborne disease outbreaks within the Netherlands (Simone *et al*., 1997), USA (Woodward *et al*., 1970), Finland (Hirn and Maijala, 1992), metropolitan France (Tremolieres, 1996), Korea and Japan (Lee *et al*., 1996), respectively. About 9 and 19% of the incidents of staphylococci food poisoning in the UK (Wieneke *et al*., 1993) and the USA (Smith *et al*., 1983), respectively, were attributed to restaurants. Furthermore, SEA is the most common enterotoxin recovered from staphylococcal food-poisoning outbreaks in the USA (77.7%; Casman, 1965) and Taiwan (81–90%; Ko and Chang, 1995).

Staphylococcal food poisoning results from the consumption of a food in which enterotoxigenic staphylococci have grown and formed enterotoxin. In

restaurant foods, only five out of nine enterotoxins or combinations of them have been detected. Recognition of the sources of transmission and outbreaks of enterotoxigenic staphylococci are important to prevent this type of food poisoning. Furthermore, the implementation of some measures, such as food hygiene inspection and training, the implementation of the HACCP, SCAP (self-care action program), SAFE (sanitary assessment of food environment) and TQM (total quality management) systems, can help to guarantee food safety in restaurants (Soriano *et al*., 2002a).

In the USA, the Environmental Health Specialists Network (EHS-Net), a network of environmental health specialists and epidemiologists at federal and state health agencies, whose mission is to improve environmental health practice conducted a study with a primary goal of improving the understanding of the underlying causes of foodborne illness using a system-based approach (Green *et al*., 2005). As part of this ongoing effort, EHS-Net analysed data from a telephone survey of food service workers designed to increase understanding of food preparation practices (a cause of foodborne illness) in restaurants. Results indicated that risky food preparation practices were commonly reported. Respondents said that at work they did not always wear gloves while touching RTE food (60%), did not always wash their hands or change their gloves between handling raw meat and RTE food (23 and 33%), did not use a thermometer to check food temperatures (53%) and had worked while sick with vomiting or diarrhoea (5%). Several factors were associated with safer food preparation practices. Workers responsible for food preparation reported washing their hands and wearing gloves when handling RTE food more often than workers not responsible for food preparation. Workers who cooked reported changing their gloves more often than workers who did not cook. Older workers and managers reported washing their hands more often than younger workers and non-managers.

Workers in chain restaurants more frequently reported using thermometers than workers in independently owned restaurants. This study provided valuable information concerning the prevalence of food preparation practices and factors that may impact those practices. Additional research is needed to better understand those factors.

Food hygiene and safety have never had such a high profile within the catering industry. The continued rise in food-poisoning outbreaks and the emergence of hygiene problems with particular foods have given consumers a greater awareness of food safety. Since 1990, the catering industry has undergone a great deal of change. It has now become, in many sectors, a high-tech industry. Unfortunately, the level of awareness of food hygiene and food quality has not kept pace with these developments (West, 1992).

More than half of the respondents indicated that a thermometer was not the method they used most often to check whether foods were sufficiently cooked. The FDA provides recommended cooking temperatures for a variety of foods, particularly meats and poultry, to ensure that food reaches a temperature high enough to kill pathogens. Checking temperatures with a thermometer helps ensure that food meets these recommended temperatures. Their results suggested, however, that workers use a variety of methods, other than a thermometer, to determine when food is sufficiently cooked. Workers said they checked cooked foods by the length of time the food cooked and by the appearance and feel of the food (Green *et al*., 2005).

A small percentage of workers reported working while sick with vomiting or diarrhoea. Several factors were found to be associated with safe food-handling practices, including respondent's age, work responsibilities and the type of restaurant in which respondents worked. Older workers compared to younger ones and those with management responsibility compared to those without such responsibility reported washing their hands more often. These associations may reflect the impact of experience or knowledge on food preparation (Green *et al*., 2005).

However, other studies have found that even when food service workers demonstrate good knowledge of food safety, they do not always engage in safe preparation practices (Clayton *et al*., 2002). These findings suggest that other factors, in addition to knowledge and training, influence preparation practices. No doubt, Lord Plumb's elaboration of Bauman's innovation to longitudinally integrated safety assurance (LISA), i.e. from the farm or estuary to the consumer's plate (Mossel, 1991) greatly facilitated this adoption as later testified by Bauman himself (Bauman, 1995). The sequential measures of intervention to be taken in this context rely on the so-called Wilson Triad (Mossel and Struijk, 1993; Wilson, 1935). This was the first explicit maxim striving after the management of contamination, recontamination and colonisation.

The Wilson Triad approach to processing foods for safety is presented below (Mossel and Struijk, 1993).

1. Elimination of organisms, negatively affecting food safety at a sub-sterilisation lethality level, as dictated by risk analysis, by two types of measures of intervention:

- Keeping the initial colonisation of raw materials to a minimum, with respect to both pathogens and bacteria producing enterotoxins, biogenic amines and endotoxins, whose adverse health effects cannot, as a rule, be contained by the subsequent decontamination treatment.
- Adjusting microbial lethality of processing to a level ensuring a wholesome final product, though compatible with sparing nutritive value and sensory attributes, by relying on preventive measures ensuring paucimicrobial raw materials.

2. Avoiding recontamination of treated commodities which would not only nullify the effect of the microbial reduction process, referred to less than 1, but in addition constitute an increased hazard in products, which, as a result of the decontamination step, would be devoid of most of the competing organisms which in raw products keep pathogens under control. This should rely on validated measures of prevention including either processing after hermetic packaging, or else aseptic packaging of the treated commodity.
3. When commodities are colonisation-prone, i.e. lack of intrinsic antimicrobial protection, ensuring distribution and storage of the final product under conditions arresting or at least markedly delaying the proliferation of the infinitesimally low numbers of pertinent viable organisms:
   - Surviving processing step 1.
   - Sporadically contaminating the final product, despite all attainable, maintainable and affordable precautions taken, during aseptic packaging, or, similarly, aspired into packaged treated product.

Good catering practices and procedures depend on provision of appropriate training in food and personal hygiene for food handlers; understanding and complying with current legal requirements by catering and hospital management; and planned preventive maintenance of plant by estates departments. Food hygiene is more than cleanliness. It means the use of policies, practices and procedures to protect food from contamination, prevent multiplication of bacteria to numbers capable of causing food poisoning or food spoilage and ensure the destruction of disease-producing micro-organisms by thorough cooking (Barrie, 1996).

In the catering environment or in fast food restaurants, the consumer has no option but to assume the beefburger has been cooked effectively and so the restaurant has complete responsibility for ensuring this is carried out properly. Again, the key to controlling the hazard is to have established validated procedures for ensuring that all products, when cooked on the heating equipment provided, achieve the correct internal temperature when cooked according to the prescribed method. The cooking time and temperature must take account of all of the variables previously described that affect the achievement of the correct internal temperature and it is important that such procedures are supported by checks conducted at the start of the day and repeated at intervals throughout the day (Bell and Kyriakides, 1998).

In a Japanese outbreak of *E. coli* O157 (http://www.sproutnet.com/Press/silence_of_the_calves.htm), it is possible that the implicated radish sprouts may have resulted in only a restricted and small outbreak if the conditions of further processing, handling and distribution to children in their lunch boxes had been controlled to prevent further growth. Catering facilities should be operated in a way that ensures consistent application of high standards of hygiene to prevent cross-contamination from raw to RTE products, and from infected individuals, to products (Bell and Kyriakides, 1998).

Investigations of several other outbreaks of listeriosis have implicated food supplied by caterers as the source of the causal organism. An outbreak of listeriosis in north-east England affecting four patients of two hospitals, one of whom died, was linked to the consumption of sandwiches (cheese, cheese and salad) prepared by a single caterer. The outbreak strain, *L. monocytogenes* isolated from two of the patients, was indistinguishable from the strain recovered from a cheese and salad sandwich (Bell and Kyriakides, 2005).

A large outbreak of *Clostridium botulinum* occurred in Canada in 1985. A total of 36 people suffered botulism linked to the consumption of food at a restaurant in Vancouver, British Columbia (Blatherwick *et al*., 1985). The first recognised cases were two sisters and their mother who had eaten at the restaurant and the subsequent cases were only identified after a general alert was raised. It transpired that all of those affected had eaten at the implicated restaurant, although the outbreak occurred in two clusters between July and September 1985 (Dodds, 1990).

The examples of food-associated outbreaks of illness caused by micro-organisms are given in Table 8.1. The flow diagram of food caterers which receive, maintain, prepare, process and distribute sweets inside the business and to other businesses (confectioneries) is shown in Fig. 8.1.

8.1.1 Prerequisite programmes

It has been recommended that before HACCP is utilised, a PRP is needed (Seward, 2000). If the PRP is not used, there probably will be a waste of resources

Table 8.1 Examples of food-associated outbreaks of illness caused by micro-organisms.

Food	Country	Establishment	Micro-organism	Cases	Reference
Sandwich	Greece	Airplane	*Salmonella enteritidis*	415	Lambiri *et al.* (1995)
Lunches containing radish sprouts	Japan	School	*Escherichia coli*	6309 (3 deaths)	Fukushima *et al.* (1997)
Bottled chopped garlic in soybean oil produced in USA	Canada	Restaurant	*Clostridium botulinum*	36	Bell and Kyriakides (2000)
Turkey	USA	Buffet	*Staphylococcus aureus*	162	Soriano *et al.* (2002a)
Chicken salad	USA	School restaurants	*Staphylococcus aureus*	1364	Soriano *et al.* (2002a)
Ham salad sandwiches	USA	School restaurant	*Staphylococcus aureus*	600	Bergdoll (1989)
Pressed pork and chicken	USA	Roadside restaurant	*Staphylococcus aureus*	9	De Saxe *et al.* (1982)
Cooked chicken	USA	School lunch	*Staphylococcus aureus*	71	De Saxe *et al.* (1982)
Imported canned mushrooms	USA	Restaurants	*Staphylococcus aureus*	99	Levine *et al.* (1996)
Scrambled eggs	Japan	Cafeteria	*Staphylococcus aureus*	21	Miwa *et al.* (2001)
Ham	USA	School restaurants	*Staphylococcus aureus*	10	Richards *et al.* (1993)
Pre-packed chicken	UK	Restaurant	*Staphylococcus aureus* *Bacillus cereus*	70	Robinson *et al.* (1989)
Eclairs	Thailand	College restaurant	*Staphylococcus aureus* *Bacillus cereus*	400	Thaikruea *et al.* (1995)

and money and might cause more resistance for future utilisation and HACCP system implementation. A PRP, which supports a HACCP plan, also called standard operating procedures (SOPs), includes good personal hygiene (employee hygiene practice), cleaning and sanitation programmes (environmental hygiene practice), proper facility-design practices, equipment-maintenance, and supplier selection and specification programmes (cross-contamination control; National Restaurant Association Educational Foundation, 2002).

One hundred and two small- and medium-sized food businesses in the UK were quantitatively assessed for HACCP and PRP implementation by Walker *et al.* (2003). The assessment was conducted in person using a generic HACCP–PRP questionnaire from the point of ingredient purchase through to consumer service. Since the questionnaire was completed on the business premises, managers' claims regarding food safety issues could be verified. Scores were awarded for the implementation of time, temperature and cross-contamination controls. These parameters were considered as essential for the control of microbial hazards. Temperature control was the activity least likely to be implemented due to 60% of businesses using domestic refrigerators for commercial purposes and only 40% having temperature probes. The survey revealed that only 65% of businesses kept any form of records. These were primarily temperature logs and delivery notes which were kept for up to ten years with no apparent reason. The study showed that the proposed European Union legal requirement of full (seven stage) HACCP in all businesses may present problems for small- and medium-sized multi-product businesses lacking in-house knowledge and access to experts.

8.1.2 Studies of HACCP in food service areas

In a study carried out by Soriano *et al.* (2002a) in a university restaurant, it was found that the HACCP system did improve the microbiological quality and they claimed that the implementation of HACCP improved food safety of some university restaurants when their microbiological quality was compared before and after introduction of HACCP (Soriano *et al.*, 2002b). However, it was also shown that the HACCP system was often not implemented correctly due to limited working space and low numbers of employees. Solutions were also recommended by Soriano *et al.* (2002a) which suggested that restaurants need to offer documented training for personnel in hygiene, GMP,

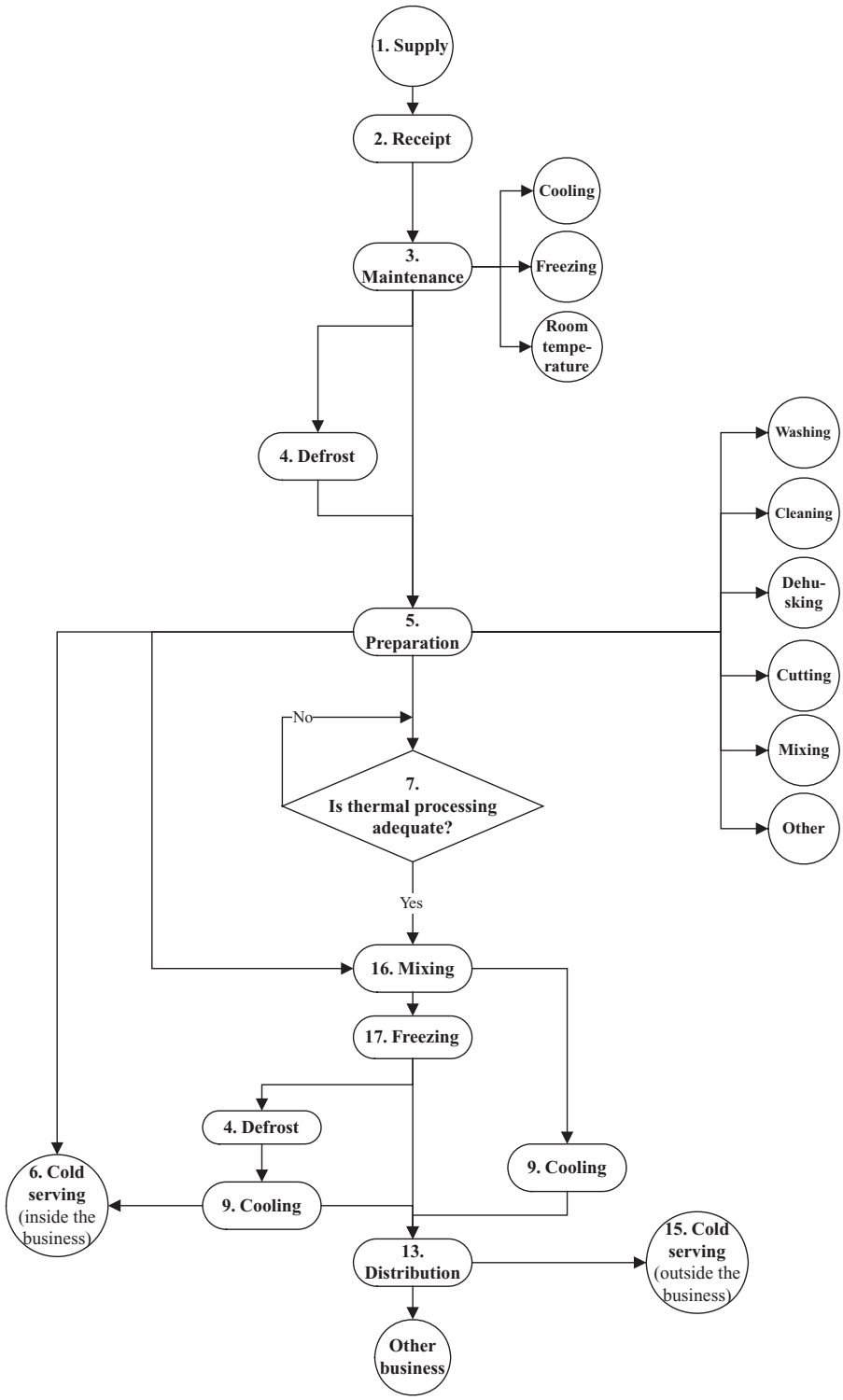

Fig. 8.1 Flow diagram of food businesses which receive, maintain, prepare, process and distribute sweets inside the business and to other businesses (confectioneries).

cleaning and sanitation procedures, and personal safety to avoid the problems of cross-contamination.

Martinez-Tome *et al.* (2000) checked the safety of salads in four school kitchens by sampling and collecting their salads, then presenting the results to the employees, and then educating and training the kitchen workers. After that, a decrease of microbial population was observed. This also indicated that the knowledge of hygiene practice of food handlers can be a CCP. Food production in four school kitchens was checked in order to improve food safety by establishing a self-regulated control system based on GMPs and as an introduction to HACCPs. A form, which referred to different aspects such as the cleanliness of the installations, personnel hygiene and the prevention of cross-contamination, was used to obtain the necessary data. Furthermore, foods thought to be of high risk were periodically collected for microbiological analysis. Samples for microbiological examination were taken from cutting boards, tables, machines, knives and ingredients (on-line sampling). The results were used as a basis for the training of food handlers with the aim of improving the safety of salad preparation, in accordance with GMPs. It was noted that hygiene improvement depended on chlorine levels in the rinsing water. Several controls for raw materials, cold storage, freezers and available chlorine levels in water were proposed (Martinez-Tome *et al.*, 2000).

Furthermore, it has been reported by Kassa *et al.* (2001) that to evaluate the marginal utility of microbial testing for minimising potential risks of foodborne outbreaks in restaurants, swab samples were taken from hand washing sink faucets, freshly cleaned and sanitised food-contact surfaces, and from cooler or freezer door handles in 70 of 350 category-three (high-risk) food service operations in Toledo, Ohio. The swabs were inoculated onto different selective media, and standard procedures were used to identify pathogenic and non-pathogenic bacteria. Microbiological evaluations of the sampled food service operations were compared with visual inspection reports, using a numeric rating scale. Enteric bacteria (that may indicate faecal contamination) were found on food-contact surfaces, on cooler or freezer door handles and on hand washing sink faucets in 86, 57 and 53% of the food service operations, respectively. Approximately 27, 40 and 33% of the restaurants received visual ratings of very poor to poor, fair, and good to very good, respectively. In comparison, 10, 17 and 73% of the restaurants received microbiological rating scores of very poor to poor, fair, and good to very good, respectively. Restaurants with trained personnel received significantly higher visual rating scores than restaurants without trained personnel ($p < 0.01$). The microbiological quality of 1012 hot meals prepared in 33 countries that were served on aircraft from 1991 to 1994 was monitored by Hatakka (1998). The study found that the microbial conditions of many samples exceeded the acceptable standards recommended by the Association of European Airlines (AEA) and the numbers varied considerably depending upon the countries where the foods were prepared.

Since 1995, all proprietors of food businesses in the UK have been required to carry out hazard analysis that included and covered five of the seven HACCP principles in the food service areas (Walker and Jones, 2002). It has been suggested that HACCP in the food service needs to be flexible (McSwane *et al.*, 2003) and the use of generic approaches of HACCP in food service is better for the future full HACCP implementation (Walker *et al.*, 2003).

In all outlets, the most significant factors that might cause illnesses are: (i) ineffective temperature monitoring, (ii) poor staff hygiene awareness, (iii) cross-contamination due to bad practices, (iv) poor hand washing facilities and (v) inadequate awareness of hygiene requirements on the management.

Results of the implementation of the HACCP system show a lower incidence of studied microorganisms following implementation (or as a result of HACCP implementation). On the other hand, a documented programme of training in personal hygiene, GMPs, cleaning and sanitation procedures and personal safety, in addition to the rearrangement in the infrastructure of these establishments, might further improve the microbial quality of the meals served (Soriano *et al.*, 2002a).

8.2 NEW TECHNOLOGIES

A new production technology for gyros (a roasted meat-based food served with potatoes) has been described by Pexara *et al.* (2007) based on the principles of 'cook–chilled' systems for food preparation. It involves two stages of cooking, rapid chilling and packaging in impermeable plastic pouches.

The new product is considered precooked, marketed under refrigeration or frozen and has only to be microwave reheated before consumption. The thermal processing assures the product's safety (minimum FP_{70} value of 9.81 minutes). In a shelf-life study, the product's microbiological and sensory quality was monitored during storage at 4°C. It was still acceptable after four weeks. The effect of frozen storage on processing yield, chemical composition, pH values, shear-force

values and sensory attributes of the product was evaluated. The different methods of storage did not affect the product's quality and the yield surpassed 84%. The new product had almost half total fat content in comparison to traditional gyros and 33.3% increased monounsaturated/saturated fatty acid ratio (M/S) in comparison to traditional gyros. Eighty per cent of participants in a consumer panel would have chosen to consume the new product instead of traditional gyros. This percentage reached 87.5% if it was labelled as 'reduced fat gyros'.

Many scientists have expressed concerns about the microbiology of gyros during cooking, cooling and reheating. Potential problems might arise from the fact that the cores of gyros are exposed to critical temperature ranges (25–45°C) for a long period of time allowing bacteria to grow during cooking, and these problems are increased when the heat source has to be turned down or off for a long time, usually after the noon rush time is over or at the end of the day (Kayisoglu *et al*., 2003).

8.3 ATTITUDES AND BELIEFS TOWARDS RTE MEALS

The choice of food is influenced by several factors. Among the most important factors are the consumers' expectations about the food and its consumption. Ahlgren *et al*. (2004) investigated the beliefs about the prototypical attributes of ready meal consumers and whether these beliefs have any actual basis when compared with self-reported behaviours of ready meal consumers. In a survey, respondents described what they considered to be common attributes of ready meal consumers. Some of these attributes were supported by the data provided by the ready meal consuming respondents, while many were not. Two frequently mentioned attributes, being alone and having no interest in cooking or food, were confirmed by the ready meal consuming respondents in the actual eating situation but not by their lifestyle and beliefs in general.

Another confirmed belief was that the ready meal consumer felt stress and time pressure. The study did not show, however, that the ready meal consuming respondents felt more stressed than the non-ready meal consuming respondents did. The sales of one-portion ready meals are steadily increasing in Sweden (Olsson, 2003). In 2001, Sweden had the second highest consumption of frozen ready meals in Europe (7.7 kg per capita). Convenience is one of the positive attributes of ready meals. Other attributes are that they save time and that they are suitable when eating alone. However, when ready meals receive attention in the media, it is most often the fat content or nutritional status that is highlighted, because they are usually found to contain relatively too much fat but still too little energy to meet the needs of an adult. Costa *et al*. (2002) described the expressions of Dutch senior citizens regarding their beliefs about ready meals. Positive feelings associated with ready meal consumption, such as being relaxed and spending less time and energy on cooking, were counteracted by a sense of guilt and regret at not preparing meals from scratch. The negative feelings were not only associated with concerns like eating junk food or being incapable of preparing a proper meal by oneself, but also with being afraid to be, or appear to be, lazy, laid-back or careless.

Worsfold and Worsfold (2005) reviewed the approach used to raise HACCP awareness by the local authorities of South East Wales Food Group. The group commissioned the design, delivery and evaluation of a hygiene and HACCP training course for caterers. Questionnaires were used to evaluate caterers' knowledge and perceptions of, and attitudes towards, hygiene and HACCP before, during and after training. A final questionnaire was mailed out to participants several months after the training course had finished. The results showed that prior to training, the understanding of HACCP, hazards, risk and risk management was low. The results also showed that caterers were not hostile to this system of food hygiene management. Following training, participants showed a greater awareness of HACCP but their perceptions of risk were still low. Some participants claimed to have implemented the HACCP system in their business following training whilst many caterers believed that additional assistance would be required to help them proceed with HACCP implementation.

8.4 DIFFERENT PRODUCTS MANUFACTURED IN CATERING

Hamburger disease is caused by a specific type of bacteria, called *E. coli* O157:H7, which lives in the intestines of cattle, and can be transferred to the outer surface of carcasses when cattle are slaughtered. In addition, other pathogens that are also found in beef patties are *Listeria innocua* and *Salmonella* serotypes (Murphy *et al*., 2002). Meat patties should be cooked to a certain internal temperature and held there for the proper time period to avoid microbial hazards. FDA has recommended a minimum target cooking temperature of 71°C with a 15-second holding time for food service operations to enhance food safety (FDA, 1999).

Pan-frying, a very popular cooking method, imparts an aromatic, savoury flavour to the patties (Gisslen, 1999). There are several factors affecting the heat and mass transfer in the patties during cooking, such as cooking temperature and time, and physical and thermal properties of the patties (Berry, 1996). To improve the quality of cooked patties while ensuring food safety, it is necessary to systematically study the influences of different cooking conditions. The simulation of the heat and mass transfer and microbial destruction models can assist in the development of optimum process conditions for the preparation of high-quality and safe patties.

The predictive mathematical heat and mass (water and fat) transfer models for the double-sided pan-frying of unfrozen and frozen hamburger patties were developed and validated against experimental data by Ou and Mittal (2006). The simulation results demonstrated the inactivation of *E. coli* O157:H7, *Listeria innocua* and *Salmonella* serotypes within patties during cooking. The effects of various patty thickness and pan temperature on safe process time were analysed. For a safe patty, double-sided pan-frying with 160°C pan temperature is recommended due to its faster cooking and better microbial safety. The cooking times for double-sided pan-frying of frozen and unfrozen patties are approximately 293 and 115 seconds, respectively. The increase in heating temperature resulted in higher rates of patty centre temperature increase and water and fat losses, and decreased the process time for 12 log reductions of micro-organisms. An increase in the thickness of the patty resulted in an increased process time.

8.4.1 Eggs

The local authorities of the city of Antwerp (Belgium) determined dioxin levels in eggs from free-range hens owned by private owners in the northern districts of Antwerp (Pussemier *et al.*, 2004). The reasons for this survey stemmed from fears that free-range eggs could be contaminated by local environmental sources (e.g. soil, grass, earthworms) as a result of the presence in this area of intensive industrial and domestic activities. The analyses revealed high levels of PCDD/F (polychlorinated dibenzodioxin and dibenzofuran) in the home-produced eggs (average = 9.9 pg WHO-TEQ per gram of fat; $n = 15$). An evaluation of the available results has been carried out by the Scientific Committee of the Belgian Federal Agency for the Safety of the Food Chain. From this evaluation, it appeared that the analysis of congener profiles was of limited use because all profiles were dominated by the OCDD (1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin) congener, independently of the level of contamination. There were not enough indications allowing a causal link to be established between high dioxin levels in eggs and soil contamination and, on the other hand, it was assumed that other factors such as feeding habits, physiological state and egg laying rhythm of the hens could not be ruled out as potential causes of aggravation. A quick risk assessment led to the conclusion that the impact of this contamination is highly relevant for the consumer's health due to the important contribution of such home-produced eggs in the estimations of total body burden.

8.4.2 Minimally processed vegetables

Despite the fact that minimally processed (MP) foods of plant origin, such as vegetables, are colonised mainly by saprophytes and plant pathogens they also carry human pathogens (i.e. *E. coli*, *Salmonellae*, *Listeria* etc.) and have caused numerous epidemic outbreaks in the past (Legnani and Leoni, 2004).

Quality systems such as good agricultural practices (GAPs) have recently been recommended for farms, to provide a basis for the development of best practice in the production of horticultural products (e.g. fruits, vegetables, potatoes, salads etc.) (Codex Alimentarius Commission, 1997a,b). HACCP's implementation effect in the microbiological quality of minimally processed vegetables was investigated by Kokkinakis and Fragkiadakis (2007), in mass-catering establishments: two big hotels, two universities and two major hospitals. Only one of each category had implemented HACCP and was purchasing vegetables produced with GAP. Samples from tomatoes in each food-processing step, water and personnel's hands were analysed microbiologically. In total, 240 tomato, 24 water and 60 personnel's hands samples were analysed. Tomatoes produced with GAP exhibited low microbial levels compared with conventional ones, while vegetable-sanitation decreased microbial levels. Salads were safe in establishments applying HACCP methodology: Microbial-level mean values (cfu/g) of *E. coli* was <20; total coliforms 3.67–3.88 $\log_{10}$; aerobic plate count 4.69–5.07 $\log_{10}$. The application of GMPs and good hygiene practices as parts of HACCP implementation was found critical for the quality of the products. Based on actual results they present recommendations for a safer mass catering.

8.4.3 Seafood

Landeiro *et al.* (2007) described the hazard analysis carried out on the manufacture of four seafood dishes at a traditional restaurant in the city of Salvador,

Brazil. In the state of Bahia, Brazil, 67,376 people reporting symptoms of febrile illness and gastroenteric disease, associated with restaurant and street feeding in most of the cases, were admitted to hospital in 2000.

These analyses consisted of detailed studies of the manufacture process of 'moqueca de peixe', 'bobo de camarao', 'mariscada' and 'casquinha de siri'. The seafood dishes were usually cooked at temperatures that should have killed vegetative forms of foodborne pathogens. The preparation of the traditional dishes include ingredients such as seafood, red palm oil, coconut milk and spices. The following seafood dishes were selected for investigation: 'moqueca de peixe' (fish, palm oil, coconut milk, tomato and seasoning), 'casquinha de siri' (crab meat, palm oil and seasoning), 'mariscada' (lobster, crab, shrimp, crawfish, mussel, squid, octopus, palm oil, coconut milk, tomato and seasoning) and 'bobo de camarao' (shrimp, ground cassava, palm oil, coconut milk and seasoning).

Cooking is the only heat process for hot entrée items in a cook/serve food service system and hence represents 100% of the processing requirement. Cooking must ensure that pathogenic micro-organisms do not survive the process to reduce the risk to public health. The hot-holding stage was considered a CCP in the preparation of 'casquinha de siri' because of the possibility of cross-contamination and the creation of a biological hazard.

Hazards on CCPs were primarily associated to high counts of staphylococci TNase-coagulase positives mainly in 'casquinha de siri' ready to eat, held for 15 hours before distribution, and detection of *E. coli* strain producing cytotoxic necrosing factor type 1 on hands of food handlers. The control measures and monitoring procedures for seafood dish preparation were suggested.

In many Mediterranean countries, large, double-decker, cold seafood dishes constitute a popular hors d'oeuvre or, dependent on size, a main course. The platters contain both cooked items (crustaceans) and raw ones (molluscs). The process of composing this speciality item presents ample opportunities for cross-contamination of the cooked items, or the food preparation area from the raw foods. As the dishes are mostly ingested within an hour or so after being served, only seafoods containing enteric pathogens with very low minimal infectious ranges (MIRs) are fraught with risks (Mossel *et al.*, 1999).

8.4.4 Roast beef

A local health department inspected one outlet of a large, multinational catering company. A temperature measurement of roast beef being served from a carving station was at 58°C. The health department cited the caterer for not serving the roast beef at 60°C according to hot-holding regulations. The caterer removed the product from their menu, as heat lamps could not consistently assure a 60°C product temperature. The caterer could not raise the holding temperature as, higher initial roast beef temperatures would overcook the product and negatively affect quality (Kivela *et al.*, 2002).

A risk assessment and risk management strategy specific for serving rare roast beef was developed by Baker (2002). The documentation clearly and scientifically demonstrates how physical processes for cooking, hot holding, service and cooling were validated to support the company's commitment to food safety and business excellence. Working instructions for each step of preparation and service of rare roast beef were validated. A specific HACCP plan was developed to manage the daily adherence to the working instructions. This HACCP plan was integrated into the overall system's approach to daily kitchen routines, so as not to place undue burdens on staff or management. Food safety objectives enable the company to communicate why the procedures to serve rare roast beef are safe. This rational approach to linking the explanation of procedures with safety is important for internal training, long-term programme stability and external public relations.

The product is made from commercially supplied, cuts of tender loin, purchased according to strict specifications. The weight specification (3.5–5 kg) must be maintained, otherwise the validated cooking process specification could be invalidated. Only maximum weight cuts of beef were used for validation tests, as an extra challenge. Roast beef is cooked in a programmable, commercial convection oven. A single temperature probe, inserted into the centre of the beef, controls the cooking programme. First, beef is placed on a rack and placed in an oven at 300°C for 5 minutes to sear the outside. The oven door is opened to allow the interior to cool to ca. 90°C. The oven temperature probe is cooled in water and inserted into the centre of the roast beef at its thickest end. The oven parameters are reset to automatically control air temperature and speed. The beef is placed in the oven and cooked until the centre temperature reaches 60°C. The cooked beef is either served directly or transferred to a hot-holding cabinet that is able to maintain the roast beef at 60°C. Beef is held for the minimum time possible to maintain optimum quality. Rare roast beef is placed on a carving board and displayed under a heat lamp during service. Slices are cut upon customer demand. A small degree of temperature is lost from the roast beef product during service. The time of service is regulated to

maintain product quality and to ensure that product is completely cooled to < 7°C in 3 hours.

CCPs include receiving, cold storage, set-up and correct function of cooking, hot-holding and chilling equipment, and the time rare roast beef is presented for service is monitored (Baker, 2002).

8.5 STAPHYLOCOCCI FOOD POISONING

A wide range of foods is involved as sources of staphylococci food poisoning in restaurants (Bergdoll, 1989; De Saxe *et al*., 1982; Levine *et al*., 1996; Miwa *et al*., 2001; Richards *et al*., 1993; Robinson *et al*., 1989; Thaikruea *et al*., 1995; US Food and Drug Administration, 1992). The principal symptom of staphylococcal food poisoning is vomiting within 1–6 hours after eating contaminated food and usually followed by diarrhoea, abdominal cramping and exhaustion. In more severe cases, additional symptoms can include headache, muscle cramping, and changes in blood pressure and pulse rate (Genigeorgis, 1989; Jablonski and Bohach, 1997). Death from staphylococcal food poisoning is rare (0.03% of cases), but can occur among certain high-risk people such as infants, elderly and chronically ill individuals.

Guidelines for food handlers to avoid staphylococcal food poisoning are as follows (Soriano *et al*., 2002b):

1. Good hygiene in the kitchen is necessary.
2. Keep hot foods hot (at or above 60°C) and cold foods cold (at or below 7°C).
3. Do not store foods longer than four hours at room temperature.
4. Cool cooked foods as soon as possible using shallow, uncovered containers or covered containers vented to allow heat to escape.
5. Cool and reheat foods once only.
6. Good personal hygiene is essential.
7. Food handlers with exposed infections, such as a boil or cut on the hands, must be excluded from preparation and handling food.
8. Touch food with bare hands as little as possible.
9. Food must not be handled with bare hands after touching face or sores.
10. Hands must be washed with soap and water before preparing food.

8.6 CLEANLINESS AND SANITATION

Food service industry workers should received training in cleanliness and sanitation when handling food on the job as part of a comprehensive HACCP programme. The workers should be instructed to wear gloves, wash their hands at certain time intervals, wash their hands after certain tasks and wash their hands in a specific manner. The reasons for these guidelines are to ensure the safety of consumers and workers as well as to maintain the quality of the food product. When meats are involved, safety has to be ensured because disease-causing bacteria may be present on the raw product and in the food preparation environment. Meats, fruits and vegetables can be contaminated with enteric bacteria from exposure to manure, contaminated equipment, tainted water and human handling (Pennington, 2003). The faecal–oral transmission pathway from food service workers to customers is another hazard where hand washing can be a preventative control point.

Zhao *et al*. (1998) reported that *Enterobacter aerogenes* (10^5 cfu/cm^2) were transferred from chicken skin to hands, then subsequently 10^3–10^4 cfu/cm^2 were transferred from hands to vegetables upon handling. In the USA, the National Restaurant Association (NRA) ServSafe programme guidelines include a recommended hand washing regime. The worker should wet hands when running water as hot as they can comfortably stand (at least 38°C), apply enough soap to build up a good lather, vigorously scrub hands and arms for at least 20 seconds, clean under fingernails and between fingers, rinse thoroughly under running water and dry hands and arms using single-use paper towel. The ServSafe regime was compared to rinsing with warm and cool water and no washing/rinsing for bare hands and gloves after exposure to ground beef (approximately 10^6 cells/g) or liquid solution (approximately 10^6 cells/mL) contaminated with an ampicillin-resistant *E. coli* JM 109 strain (Courtenay *et al*., 2005).

The efficacy of alcohol-based hand sanitisers to replace hand washing was also evaluated. ServSafe, warm water rinse and cool water rinse reduced *E. coli* cells on hands by 98.0, 64.4 and 42.8% $\log_{10}$ cfu/mL, resulting in <1, 1.4 and 2.1 $\log_{10}$ cfu/mL *E. coli* on hands, respectively, from 3.6 $\log_{10}$ cfu/mL on unwashed hands. When vinyl food service gloves were worn during the hand washing treatments, gloves retained more bacteria than when only hands were rinsed or washed. From 2.9 to 3.4 $\log_{10}$ cfu/mL remained on hands when ethanol-based sanitisers were used instead of hand washing. Of all hand washing treatments tested in these experiments, the US NRA's recommended method was most effective ($p < 0.05$) in removing *E. coli* from hands and the levels remaining after this method were below the threshold of detection (<10 cfu/hand).

For many years, sanitarians have specified that the hands of food service workers should be washed and rinsed in warm or hot water to reduce the risk of cross-contamination and disease transmission. In the food service environment, it has been suggested that hand washing with water at higher temperatures contributes to skin damage when frequent hand washing is necessitated, and that insistence on hot water usage is a deterrent to hand washing compliance. Separate hand washing studies involving different water temperatures and soap types (antibacterial versus non-antibacterial) were performed. The 'glove-juice' technique was employed for microbial recovery from hands in both studies. Initial work evaluated antimicrobial efficacy based on water temperature during normal hand washing with bland soap. Uninoculated, sterile menstrua (tryptic soy broth or hamburger meat) was used to study the effects of treatment temperatures (4.4, 12.8, 21.1, 35 or 48.9°C) by Michaels *et al.* (2002) on the reduction of resident microflora, while *Serratia marcescens*-inoculated menstrual was used to evaluate treatment effects on the reduction of transient contamination.

Results of this first study indicated that water temperature exhibits no effect on transient or resident bacterial reduction during normal hand washing with bland soap. The follow-up study examined the efficacy and skin irritation potential involving water temperatures with antimicrobial soaps. Hands of participants were contaminated with *E. coli* inoculated ground beef, washed at one of two water temperatures (29 or 43°C) using one of four highly active (USDA E2 equivalency) antibacterial soaps having different active ingredients (PCMX, Iodophor, Quat or Triclosan). Skin condition was recorded visually and with specialised instrumentation before and after repeated washing (12 times daily), measuring total moisture content, transepidermal water loss and erythema. Overall, the four soap products produced similar efficacy results. Although there were slight increases in $\log_{10}$ reductions, visual skin irritation, loss of skin moisture content and transepidermal water loss at higher temperatures; results were not statistically significant for any parameter.

8.7 HOSPITALS

An outbreak of *Clostridium perfringens* (*C. perfringens*) food poisoning affected 17 of 44 (38.6%) patients interviewed on two hospital wards. A case–control study showed a statistically significant association between the consumption of roast pork and illness ($p < 0.01$). *C. perfringens* type A, untypable serotype, was isolated from samples of pre-cooked vacuum-sealed pork supplied by a local meat producer. Faults were noted in the food production process at the factory. Cuts of meat were too large and equipment to ensure rapid cooling of cooked meat was not installed. Cost improvements taken by hospitals, such as the use of commercially cooked meat, may not be consistent with the highest standards of food safety (Regan *et al.*, 1995). Amendments to the District Catering Policy were implemented to prevent further outbreaks.

High standards of microbiological monitoring of food processes should be applied to food destined for vulnerable hospital populations. Aycicek *et al.* (2004) determined the level of bacterial contamination on the hands of food handlers ($n = 30$) who work in the kitchen of a military training hospital. A total of 180 samples were collected from bare and gloved hands before and during food preparation. A total of 16 different bacteria were isolated, of which the most common was *Staphylococcus aureus* (126/180; 70%), followed by coagulase-negative staphylococci (102/180; 56.7%), diphtheroid bacilli (39/180; 21.7%), *Bacillus* spp. (19/180; 10.5%) and *E. coli* (14/180; 7.8%). Fifty-one of 60 (85%) gloved hand samples were collected during work, 57 (95%) of the bare hand samples were collected before work and all the bare hand samples collected during work were positive. Poor hand hygiene was indicated by high levels of *S. aureus* and *E. coli* on samples taken from bare and gloved hands.

The hands of food service employees can be vectors in the spread of foodborne disease because of poor personal hygiene or cross-contamination. For example, an employee might contaminate his hands when using the toilet, or bacteria might be spread from raw meat to salad greens by food handlers' hands.

Although bacterial loads on gloved hand samples were found to be significantly lower ($p < 0.05$) than ungloved hand samples, these loads were not within acceptable limits. These results showed that the hands of food handlers are an important contamination source in this establishment. In this study, 203 bacterial isolates were from right hand samples while 166 bacterial isolates were from left hand samples ($x^2 = 1.913$; $p < 0.05$). All the food handlers were right-handed. Bacterial load isolated from the inexperienced food handlers was higher than those from experienced ones ($x^2 = 2.024$; $p < 0.05$).

If used, single-use gloves shall be used for only one task such as working with RTE foods or with raw animal food, used for no other purpose, and discarded when damaged or soiled or when interruptions occur in the operation.

As a result, the poor hand hygiene and improper glove use by the food handlers were emphasised and it was concluded that the training in personal hygiene

and food safety should be improved, and inexperienced personnel should not be employed in kitchens without being well trained. On the other hand, if glove use principles are performed correctly, it may be efficacious in decreasing of bacterial load on hands; particularly, establishments where hand hygiene control cannot be performed properly or inexperienced personnel are employed.

The change in the demand of patient profiles and the changes in nutritional approaches require a new orientation in hospital catering businesses. The study of a number of themes (modes of production, the implementation of quality systems such as ISO or HACCP up to patients' beds, mastery of dinner trays assembly, order taking and the choice of menu) would tend to direct the current massive production to central kitchens while maintaining satellite kitchens with a lower production activity (Hamm, 2003).

The adenosine triphosphate (ATP) bioluminescence method has become increasingly adopted for monitoring surface cleanliness (Griffith *et al*., 1997). This method provides a real-time estimate of total surface cleanliness, including the presence of organic debris and microbial contamination. The ability to provide results within minutes, as opposed to days for microbiological testing, enables ATP bioluminescence to be used as a monitoring method within HACCP (Davidson *et al*., 1999).

ATP bioluminescence and traditional microbiological swabbing culture methods were used by Aycicek *et al*. (2006) for detection of surface hygiene on worktops, cutting boards and equipment at a hospital kitchen. A total of 280 surface samples were collected from the kitchen. The agreement between the two methods (coefficient of kappa) was statistically significant (corrected $x^2 = 30.886; \kappa = 0.249; p < 0.001$). Consequently, the ATP monitoring method provides results rapidly with improved benefits in the control of surface contamination and application of corrective action against poor hygiene. However, it is not a substitute for culturing methods, the combination of both methods was emphasised for surface hygiene monitoring. Besides, the results indicate that, for food safety and public health, the hygienic status of the surfaces in the kitchen should be improved and food handlers should be trained well on hygiene.

Data from the Regional Health Office in Italy show that between 1988 and 2000, 1564 episodes of foodborne diseases were reported, and 1139 (72.8%) of these were caused by *Salmonella* (Emilia-Romagna Region, Health Assessorship, 2002). One of the most significant risk factors identified is cross-contamination, particularly between the food and the preparation surfaces (Bisbini *et al*., 2000).

The Health District of Ferrara (Emilia-Romagna Region, Italy) has undertaken an educational programme for food personnel training in order to promote knowledge of GMPs and implementation of the HACCP system (Legnani *et al*., 2004). During the period 2001–2002, a total of 236 inspections were performed on 27 catering establishments in the province of Ferrara. A total of 370 food samples and 140 surface swabs were taken and examined for microbiological quality. The surveillance system has brought to light various shortcomings regarding the equipment (36 corrective actions) and incorrect procedures (47 corrective actions). With regard to the equipment, the most common problems identified were: inadequate extraction fans (7 centres), the lack of liquid soap and/or paper towels (6), cutlery with wooden handles (6) and wooden cutting boards (5), presence of hand-operated waste bins (5), no thermometers in the refrigerators (4), unsuitable containers for the transport of meals (3) and no blast chiller (2).

The tool and work surfaces showed an unacceptable contamination in 10% of samples. The data also highlighted a certain percentage of unacceptable samples of foods, especially with regard to *E. coli*, ranging from 5.4% for the 'first and second courses' to 10.8% for the 'raw meats and meat preparations'. Nevertheless, the hygienic quality of services and foods has improved in comparison with previous surveys, showing that the staff educational programmes and the application of HACCP principles have increased the level of awareness regarding food hygiene in those working in catering services.

There is a paucity of research evaluating the effectiveness of health and safety training conducted in the workplace. This comprehensive review amply supported the effectiveness of training. However, given the growth of computer-based instruction (CBI) formats as preferred methods of training delivery, concern is heightened because only two (Goldrick, 1990; Vaught *et al*., 1988) of Cohen and Colligan's 80 articles employed CBI. Maintaining a safe workplace in the food service industry presents a major challenge. Many kinds of injuries occur; principal types include burns and scalds from hot surfaces, substances and caustic chemicals (Baggs *et al*., 2002; Hunt *et al*., 2000; Islam *et al*., 2000; Suzman *et al*., 2001); fire dangers from grills and fryers; strains, sprains and stresses from slips, trips and falls on wet or greasy surfaces (sometimes from ladders or step stools), often in a cluttered space (Feldman *et al*., 2002); and cuts from machines or knives.

Eckerman *et al*. (2004) employed interactive CBI to 73 workers in the food services department of an urban hospital. The HACCP in hospital catering

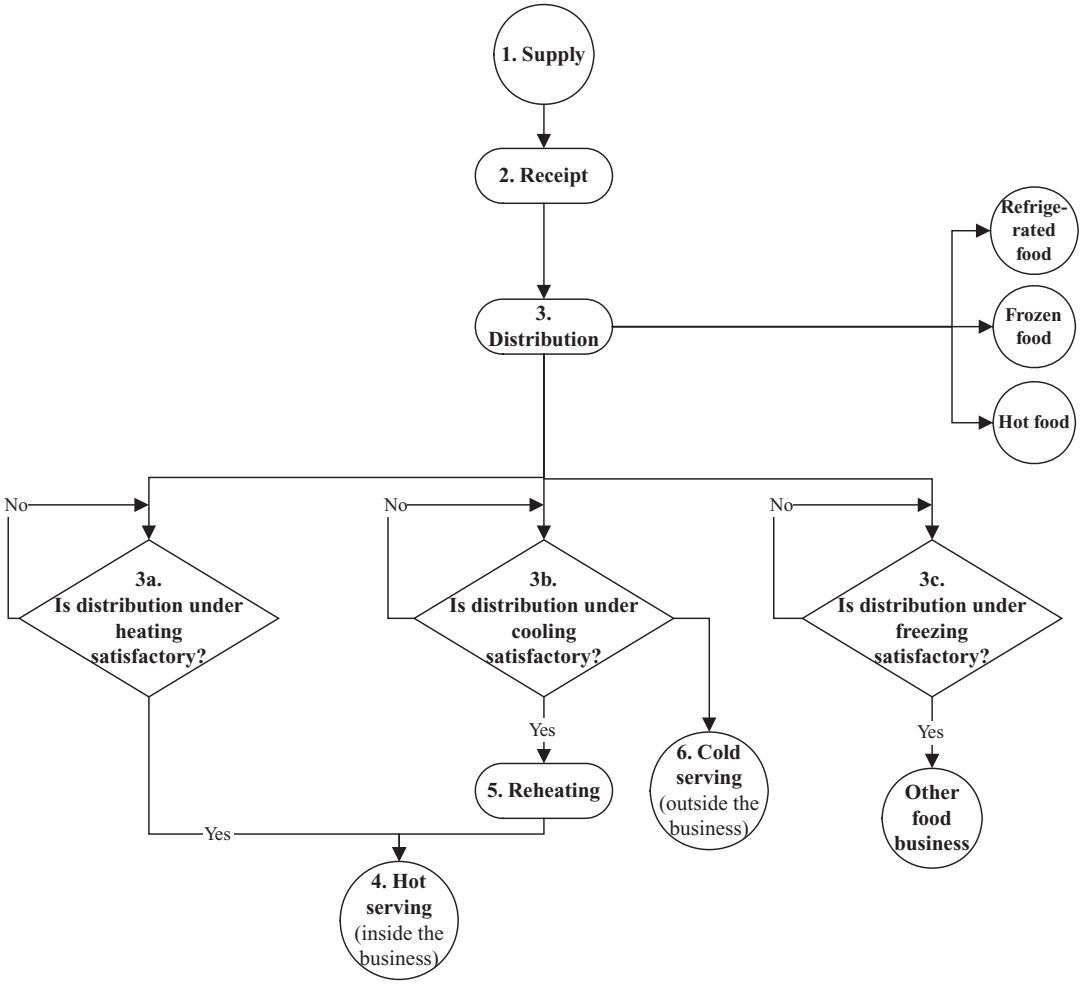

Fig. 8.2 Flow diagram of food businesses carrying out distribution of food only.

Table 8.2 HACCP in hospital catering.

Control point	Preventive action taken
Delivery of milk in glass containers with foil tops	Purchase of milk in plastic containers
Hypochlorite rinse for salads and vegetables	All vegetables to be washed with constant monitoring of hypochlorite levels
Cleaning of meat slicing machine between meat products	All meat products to be sliced at quiet time preferably in the evenings, cooked meats first, with adequate cleaning schedules between products
Control of *Salmonella* risk from eggs	Cease offering lightly boiled eggs to patients. Purchase only from local egg producers that could ensure lay-date and *Salmonella*-free flocks
Purchase and delivery of meat and poultry	Purchase only from producers able to ensure refrigerated delivery. Revision of contracts
Delivery of all perishable/frozen products at adequate temperatures	Negotiate delivery only during kitchen working hours when staff available to receive and check product and temperatures

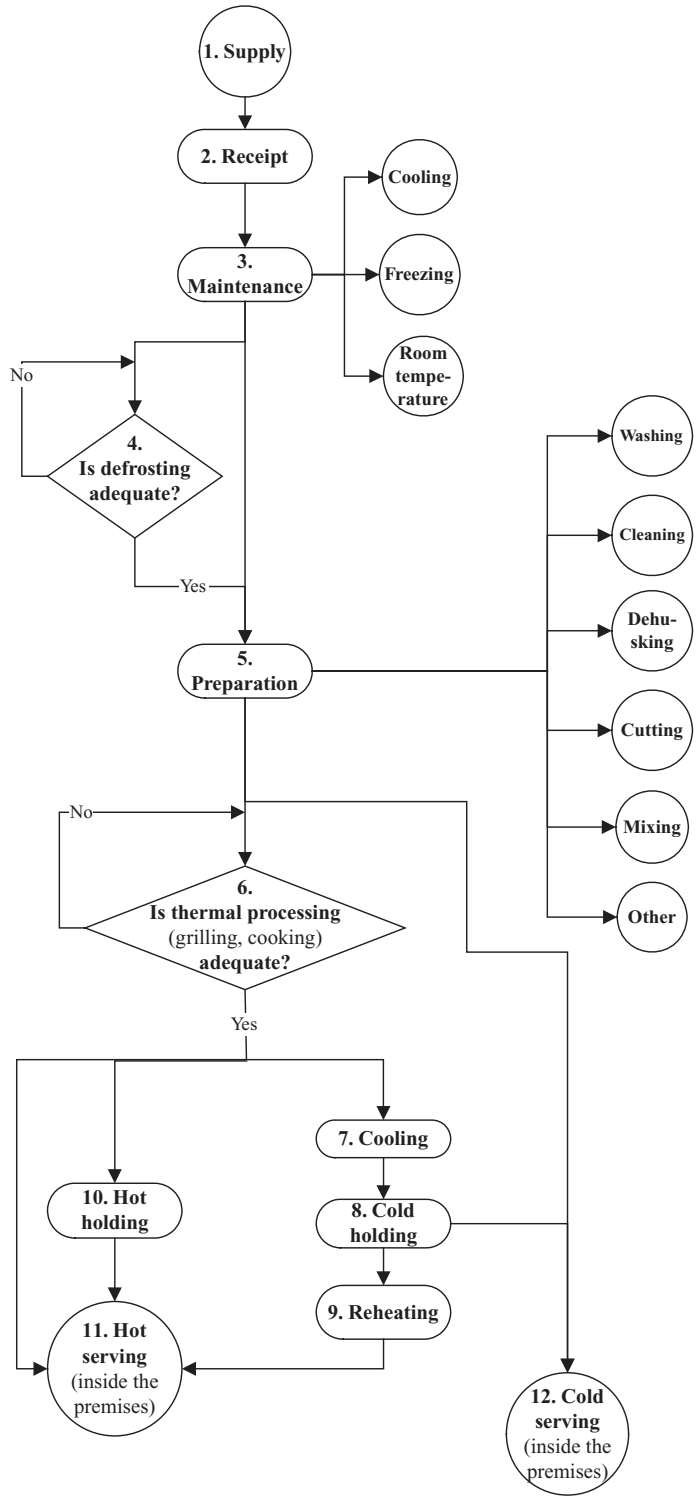

Fig. 8.3 Flow diagram of food businesses which receive, maintain, prepare, process and sell food inside the premises (restaurants).

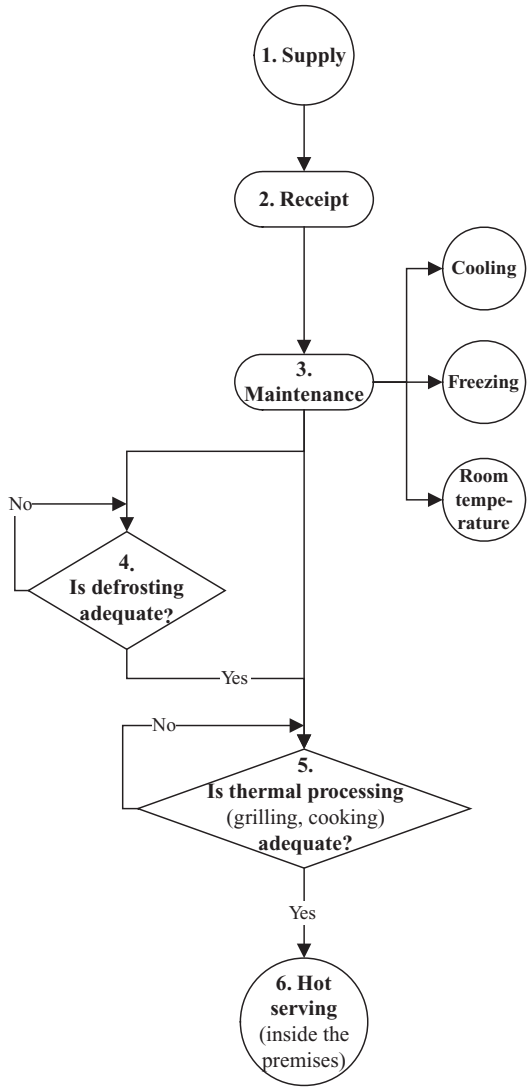

Fig. 8.4 Flow diagram of food businesses that do not prepare but process and sell food inside the premises (small scale restaurants).

is summarised in Table 8.2. Post-test accuracy (95%) improved significantly ($p \leq 0.0001$) from the pre-test (74.5%, $d = 1.09$). Generalisation was confirmed by increased accuracy in answering questions, posed on-the-job, that required application of knowledge to the work setting (from 46 to 79%; $p < 0.0001$). Problematic kitchen conditions such as puddles increased slightly after training, but adjustment for increasing production/workload revealed an overall post-training decline in problems from 0.58 to 0.32 ($p = 0.0001, d = 0.89$). Work practice improvement was seen in 79% of workers ($p < 0.0001, d = 1.00$). The effects of knowledge, location and work practice improvements are large and demonstrate that the benefits of CBI extend to the workplace floor. Further, the decrease between knowledge and behaviour change ($d = 0.09$–0.2) is less than that reported following other forms of training. This training project represents the cooperative effort of management, health and safety officials and outside consultants. The topics addressed in the training were specifically chosen by on-site management and health and safety experts to address problems encountered at this location and to address training gaps to make it comprehensive. These groups, together with the employees, provided considerable input into the

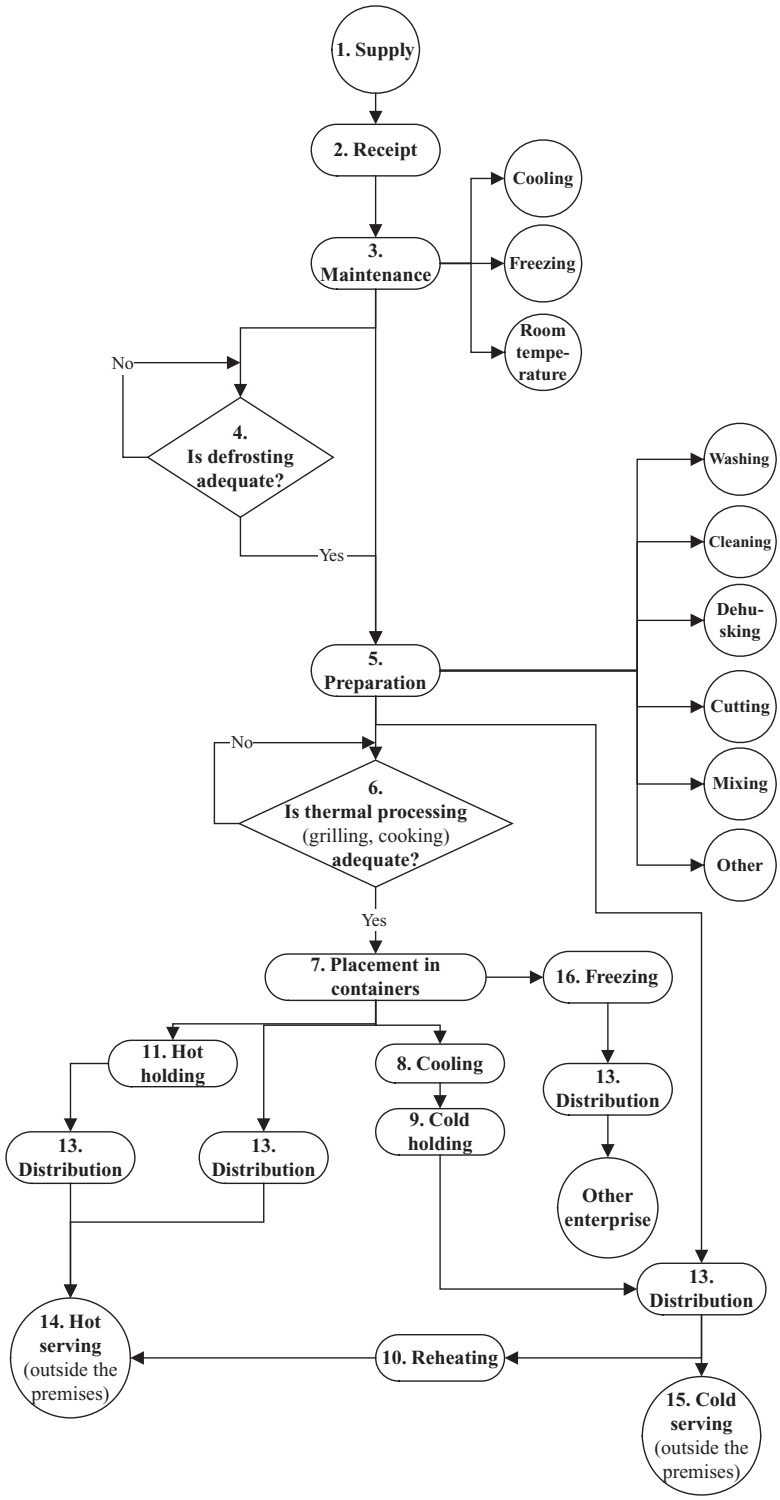

Fig. 8.5 Flow diagram of food businesses that receive, maintain, prepare, process but do not sell food inside the business but distribute unpackaged foods to other enterprises (catering for meals).

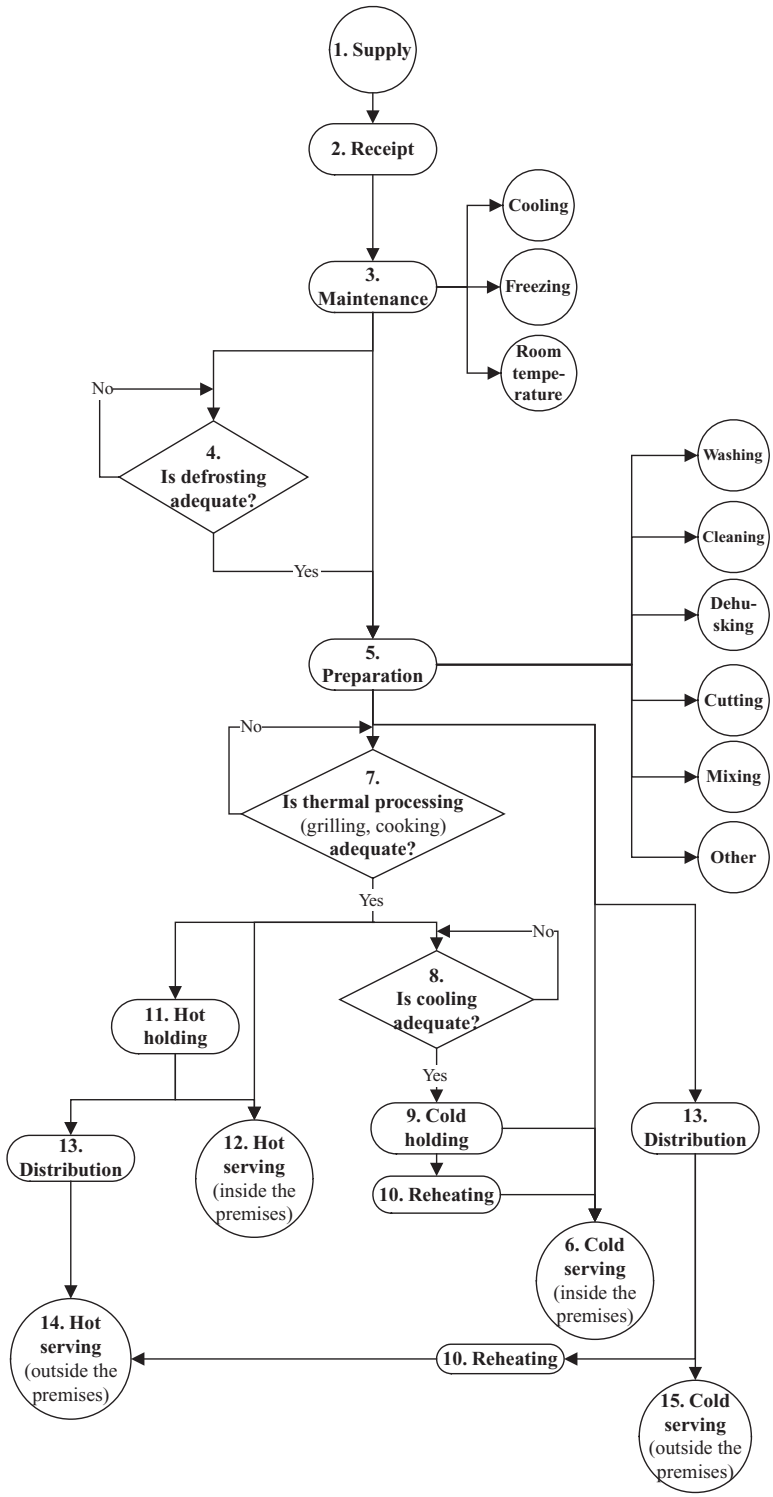

Fig. 8.6 Flow diagram of food businesses that receive, maintain, prepare, process and sell food inside the business but also distribute unpackaged foods to other premises (catering for meals).

Table 8.3 Representative HACCP plan for catering.

S/n	Processing step	Hazard	Cause	Assessment	CCP	Control measures
2.	Raw materials receiving			Severity: Occurrence		
A.	Fresh meat/frozen: • Beef • Pork • Lamb • Poultry With or without bones • Eggs	Microbiological: Presence of pathogenic micro-organisms: • *Salmonella* spp. • *Listeria monocytogenes* • *Campylobacter jejuni* • *Yersinia enterocolitica* • *E. coli* O157:H7 • *Staph. aureus* Chemical: • Presence of antibiotics • Presence of growth factors (hormones, thyreostatic etc.) • Presence of pesticide residues • Presence of disinfectant residues Physical: Foreign matter: • Wood • Glass • Plastic	Inappropriate conditions for maintenance, distribution etc. Increased temperature: $T > 5°C$ for fresh Growth and multiplication of pathogenic micro-organisms $T > -12°C$ for frozen meat Deteriorated raw material Deteriorated raw material	Severity: High Occurrence: Increased	Yes	• Raw materials specifications • Suppliers evaluation procedure (approved list) • Quality control during receipt (macroscopic, temperature measurement etc.) • Sporadic lab control • Conformity certificates from the supplier • Personnel training on quality control during receipt • Working instruction for inspections carried out during receipt of raw materials
B.	Fresh fish/frozen: • Whole fish • Fish slices/fillets • Molluscs (octopus, squid, cuttlefish) ○ Malacostracan (prawns, crawfish, lobsters) Bivalve molluscs (mussels)	Microbiological: • *Vibrio* spp. • *Shigella* spp. • *Salmonella* spp. • *Staph. aureus* • *Cl. botulinum*, E Parasites: *Anisakis* spp. Chemical: Heavy metals (Hg, Pb, Cd) Physical: Foreign matter: • Plastic • Metallic objects	Inappropriate conditions for maintenance, distribution etc. Increased temperature: $T > 3°C$ for fresh Growth and multiplication of pathogenic micro-organisms $T > -18°C$ for frozen Deteriorated raw material Deteriorated raw material	Severity: High Occurrence: Increased	Yes	• Raw materials specifications • Suppliers evaluation procedure (approved list) • Quality control during receipt (macroscopic, temperature measurement etc.) • Sporadic lab control • Conformity certificates from the supplier • Personnel training on quality control during receipt • Working instruction for inspections carried out during receipt of raw materials

(*Continues*)

Table 8.3 (*Continued*)

S/n	Processing step	Hazard	Cause	Assessment	CCP	Control measures
C.	Fresh vegetables/frozen fruits	Microbiological: Presence of pathogenic micro-organisms: • *Salmonella* spp. • *Listeria* spp. • *Shigella* spp. • *Staph. aureus* • *Cl. perfringens* Chemical: Pesticide residues Physical: Foreign matter: Soil, stones, metallic objects	Inappropriate conditions for maintenance, distribution etc. Increased temperature: $T > 8°C$ for fresh Growth and multiplication of pathogenic micro-organisms $T > -18°C$ for frozen Deteriorated raw material Deteriorated raw material	Severity: High Occurrence: Increased	Yes	• Raw materials specifications • Suppliers evaluation procedure (approved list) • Quality control during receipt (macroscopic, temperature measurement etc.) • Sporadic lab control • Conformity certificates from the supplier • Personnel training on quality control during receipt • Working instruction for inspections carried out during receipt of raw materials
D.	Dairy products • Milk • Butter • Cheese (very soft, soft, semi-hard, hard)	Microbiological: Presence of pathogenic micro-organisms: • *Salmonella* spp. • *Listeria monocytogenes* • *Cl. perfringens* Chemical: • Presence of antibiotics • Presence of mycotoxins (B_1, G_1) • Disinfectants residues Pesticide residues Physical: Foreign matter	Inappropriate conditions for maintenance, distribution etc. Increased temperature: $T > 5°C$ Growth and multiplication of pathogenic micro-organisms Deteriorated raw material Deteriorated raw material	Severity: High Occurrence: Increased	Yes	• Raw materials specifications • Suppliers evaluation procedure (approved list) • Quality control during receipt (macroscopic, temperature measurement etc.) • Sporadic lab control • Conformity certificates from the supplier • Personnel training on quality control during receipt • Working instruction for inspections carried out during receipt of raw materials
E.	Meat products: Cooked pork meats	Microbiological: Presence of pathogenic micro-organisms: • *Listeria monocytogenes* • *E. coli* O157:H7 • *Salmonella* spp. • *Staph. aureus* • *Cl. botulinum* • *Cl. perfringens* Chemical: Concentration of $NaNO_2 > 50$ ppm Physical: Foreign matter (glass, wood, metal)	Inappropriate conditions for maintenance, distribution etc. Increased temperature $T > 5°C$, growth and multiplication of pathogenic micro-organisms Deteriorated raw material Deteriorated raw material	Severity: High Occurrence: Increased	Yes	• Raw materials specifications • Suppliers evaluation procedure (approved list) • Quality control during receipt (macroscopic, temperature measurement etc.) • Sporadic lab control • Conformity certificates from the supplier • Personnel training on quality control during receipt • Working instruction for inspections carried out during receipt of raw materials

F.	Canned and dry food	Microbiological: Growth – Survival of pathogenic micro-organisms Foreign matter Destruction of packaging (cross-contamination)	Inappropriate conditions for maintenance, distribution etc. • Deteriorated raw material in cans: ○ Swollen ○ Oxidised ○ Dirty content ○ Bruised (change of shape) effect on the double seam-contamination ○ Contamination from damaged packaging	Severity: High Occurrence: Increased	Yes	• Raw materials specifications • Suppliers evaluation procedure (approved list) • Quality control during receipt (macroscopic, temperature measurement etc.) • Sporadic lab control • Conformity certificates from the supplier • Personnel training on quality control during receipt • Working instruction for inspections carried out during receipt of raw materials
2a	Receipt of auxiliary raw materials • Aromatic raw materials and essential oils • Edible oils and fat • Sweeteners • Additives	Microbiological: • Presence of pathogenic micro-organisms • Presence of toxic substances Chemical: Presence of toxic substances	Deteriorated raw material	Severity: High Occurrence: Increased	Yes	• Raw materials specifications • Suppliers evaluation procedure (approved list) • Quality control during receipt (macroscopic, temperature measurement etc.) • Sporadic lab control • Conformity certificates from the supplier • Personnel training on quality control during receipt • Working instruction for inspections carried out during receipt of raw materials
2b	Receipt of packaging materials	• Materials not suitable for food • Defective packaging		Severity: High Occurrence: Increased	Yes	• Packaging materials' specifications • Suppliers evaluation procedure • Quality certificate from supplier confirming the absence of dangers according to legislation • Personnel training for receiving/quality control
3	Maintenance					
3a	Storage at room temperature ($10°C < T < 25°C$)	Microbiological: Growth and survival of pathogenic micro-organisms	Bad storage conditions (open, damaged packages) Contamination from storage of other raw materials Poor hygienic conditions (cleaning, disinfection, pest control)	Severity: High Occurrence: Increased	Yes	• Maintaining cleaning and disinfection programme • Maintaining pest control programme • Maintaining instruction for storage

(*Continues*)

Table 8.3 (*Continued*)

S/n	Processing step	Hazard	Cause	Assessment	CCP	Control measures
3b	Cool storage: $T < 5°C$	Microbiological: Growth of pathogens	Increase of temperature/multiplication of pathogenic micro-organisms Cross-contamination between raw materials and final products Cross-contamination between packaged and unpackaged food	Severity: High Occurrence: Increased	Yes	• Control and temperature recording • Preventative maintenance of fridges • Maintenance of foods covered • Different cooling chambers for raw materials and final products (where it is feasible) • Storage instruction
3c	Frozen storage: $T < -18°C$; $T < -20°C$ for ice creams	Microbiological: Growth of pathogens	Increased temperature defrost growth/ multiplication of micro-organisms Cross-contamination between open and closed packages	Severity: High Occurrence: Increased	Yes	• Control and temperature recording • Preventative maintenance of freezers • Storage instructions • Different areas for open/closed packages • Maintenance of ice creams covered
4	Defrost	Microbiological: Growth and multiplication of pathogenic micro-organisms	• Wrong handling during defrost: ○ Inadequate defrost resulting in inadequate cooking ○ Infrequent water change ○ Extended defrost • Contamination from equipment	Severity: High Occurrence: Increased	No	• Defrost under controlled conditions • Macroscopic control of full defrost • Placement after the end of defrost in a place with controlled temperature ($T \leq 5°C$) • Personnel training for good hygienic defrost practice • Cleaning/disinfection programme
5	Preparation (cutting, cleaning, maintenance, intermediate storage [$T < 5°C$]; preparation, cleaning, cutting, intermediate storage [$T: 4 - 25°C$])	Microbiological: Growth and multiplication of pathogenic micro-organisms Chemical: Residues from disinfectant solutions on equipment and surfaces Physical: Foreign matter (plastic, metal, rope)	• Cross-contamination from raw foods to high-risk foods (ready-to-eat) • Extended stay in inappropriate temperatures ($5°C > T < 60°C$) • Sources of contamination: ○ Handling ○ Equipment ○ Packaging	Severity: High Occurrence: Increased	Yes	• Removal of packaging materials • Physical separation of preparation and handling of uncut, uncleaned and ready-to-eat food • Maintenance of minimum foods in the preparation area due to be handled • Maintaining of GMPs • Washing/disinfection of vegetables • Use of colour code for moving tools • Personnel training in GMPs • Removal of packaging materials during cleaning • Good storage practices of packaged secondary materials • Maintenance of cleaning and disinfection programme • Maintenance of pest control • Instruction for storage • Maintenance of foods covered (where possible) • Separate cooling chambers for raw materials and ready products

5b	Water	Chemical: excess of limits referred to in the Appendices A–D Directive 80/778 (water quality) Microbiological: excess of limits referred to in the appendices A–D Directive 80/778 (water quality)	Water pollution Water pollution	Severity: High Occurrence: Increased	No	• Maximum permissible limits according to Directive 80/778 • Microbiological analysis of water • Total coliforms: absence in 100 mL • Faecal coliforms: absence in 100 mL • Faecal streptococci: absence in 100 mL • Sulphur reducing Clostridia: absence in 20 mL • Total bacteria (37°C): 10/mL • Total bacteria (22°C): 100/mL
6	Cooking (thermal processing): $T \geq 75°C$; $t > 2$ minutes	Microbiological: • Survival of pathogenic micro-organisms and their toxins • Spore survival	Food not kept at the desirable temperature/time conditions	Severity: High Occurrence: Increased	No	• Temperature/time control • Cooking safety instructions • Informing the consumers that cooking in the grill and inadequate cooking could cause dangers in health
6a	Secondary processing (cutting, secondary processing except straining)	Microbiological: • Survival of pathogenic micro-organisms and their toxins • Spore survival Physical: Foreign matter (plastic, metal, rope)	Contamination from handling, equipment, foreign matter Inadequate personnel training	Severity: High Occurrence: Increased	No	• Personnel training in GMPs • Maintenance of cleaning/disinfection programme • Control of the effectiveness of cleaning surfaces (validation) • Use of colour code for moving instruments
6b	Straining (soups, broths)	Microbiological: • Survival of pathogenic micro-organisms and their toxins • Spore survival Physical: Foreign matter	Contamination due to handling, equipment, foreign matter	Severity: High Occurrence: Medium	No	• Equipment control (straining) • Personnel training in GMPs • Maintenance of cleaning/disinfection programme • Use of colour code for moving instruments
7	Intermediate storage in a warm thermochamber ($T \geq 60°C$)	Microbiological: Growth, multiplication of vegetative forms of spore-forming micro-organisms which survived during thermal processing Multiplication of *Staph. aureus*, which contaminated the food following thermal processing and toxin production	Extended stay of ready-to-eat foods at a temperature <60°C)	Severity: High Occurrence: Increased	Yes	• Temperature control of foods during their stay in the thermochamber using a thermometer with a sensor – Recording on the 'Control sheet of temperatures during storage–processing and serving' • Maintenance of foods covered • Pest control • Hygiene rules • Cleaning/disinfection programme • Personnel training • Instructions to avoid cross-contaminations

(*Continues*)

Table 8.3 (*Continued*)

S/n	Processing step	Hazard	Cause	Assessment	CCP	Control measures
8	Intermediate storage with abrupt fall in temperature ($5°C < T < 63°C$)	• Pest contamination • Cross-contamination by handling, equipment • Contamination from foreign matter		Severity: Low Occurrence: Minimal	No	• Pest control • Personnel training • Instructions to avoid contaminations • Hygiene rules • Covering • Instructions for cooling of ready-to-eat foods (abrupt fall in temperature) • Fast cooling in shallow cookware
9	Intermediate storage in cooling chambers ($T < 5°C$)	• Cross-contamination between raw materials and final products • Cross-contamination between packaged and unpackaged products • Growth of micro-organisms from handling, equipment • Contamination from foreign matter • Growth of pathogenic micro-organisms and/or toxigenesis due to increase in temperature ($T > 5°C$)		Severity: High Occurrence: Increased	Yes	• Maintenance of temperature ($T < 5°C$) • Maintenance of foods in packages • Instructions for food maintenance in cooling chambers
10	Reheating ($T \geq 90°C$)	• Survival of pathogenic micro-organisms or toxins • Spore survival when $T < 85°C$		Severity: High Occurrence: Increased	No	• Control temperature/time • Instructions for reheating of foods • Spore survival (when $T < 85°C$)
11	Hot serving ($T \geq 60°C$)	Microbiological: • Survival of pathogenic micro-organisms and their toxins • Spore survival Physical: Presence of foreign matter	• Inadequate thermal processing during stage 5 • Extended stay of foods at $T < 60°C$ (outside thermochambers) • Maintenance of foods with no protective covers	Severity: High Occurrence: Minimal	Yes	• Strict keeping of instruction 'Temperatures of receipt, maintenance, processing and serving of raw materials, intermediate and final products' • Fast procedure – direct serving or maintenance of foods with protective covers • GMPs and personnel training • Sporadic lab control
12	Serving packaging materials	• Materials not appropriate for foods • Contamination from wrong handling		Severity: High Occurrence: Increased	Yes	• Packaging materials specifications • Suppliers' evaluation procedure • Quality and conformity certificate certifying the absence of dangers according to legislation • Personnel training on quality control • GMPs training • Protection from cross-contamination • Hygiene rules • Cleaning and disinfection programme

13	Cool serving	• Growth, multiplication and toxin formation of pathogenic micro-organisms due to increase in temperature >5°C • Foreign matter contamination	Severity: High Occurrence: Increased	Yes	• Temperature maintenance within limits • Food covered (where it is possible) • Instructions for food maintenance under cooling conditions • Sporadic lab control
13a	Intermediate storage in room temperature ($5°C < T < 63°C$)	• Contamination from pests • Growth/multiplication and toxin formation from pathogenic micro-organisms which survived from thermal processing, or contaminated the food after this, due to a high stay at temperatures between 5 and 63°C • Contamination due to wrong handling and equipment • Contamination due to foreign matter	Severity: High Occurrence: Minimal	No	• Pest control • Personnel training • Protection from cross-contaminations • Hygiene rules • Coverage where possible • Storage instructions
14	Synthesis (tray preparation or trolley or placement in buffet or menu preparation before final distribution)		Severity: Low Occurrence: Minimal	No	
14a	Menu set up	• Contamination from handling, equipment, personnel: *Shigella* spp. Hepatitis virus A *St. aureus* • Wrong menu for consumers having special diets	Severity: High Occurrence: Minimal	No	• Personnel training • Protection from cross-contamination • Hygiene rules • Cleaning and disinfection programme • Instruction for labelling menu for customers of special diets • Instructions for distribution
14b	Receipt from kitchen	• Contamination from handling, equipment, personnel: *Shigella* spp. Hepatitis virus A *St. aureus*	Severity: High Occurrence: Minimal	No	• Personnel training • Protection from cross-contamination • Hygiene rules • Instructions for distribution • Distribution in closed containers or with foods having protection covers
14c	Serving	• Contamination from wrong handling, equipment	Severity: Low Occurrence: Minimal	No	• Personnel training • Instructions for protection from cross-contamination • Hygiene rules • Cleaning and disinfection programme • Practices for hygienic serving

Table 8.4 Comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with prerequisite programmes (PRPs) for catering.

Process stage	CCPs of HACCP	PRP (ISO 22000?)	CCPs of ISO 22000
Raw materials receiving (meat, fish, vegetables, fruits, dairy)	1	No	1
Receipt of auxiliary materials	2	No	2
Receipt of packaging materials	3	No	3
Maintenance		Yes	
Storage at room temperature	4	No	4
Cool storage	5	No	
Frozen storage	6	No	
Defrost		Yes	
Preparation (cutting, cleaning etc.)	7	No	5
Cooking		Yes	
Secondary processing		Yes	
Straining		Yes	
Intermediate storage in warm thermochambers	8	No	
Intermediate storage in cooling chamber	9	No	
Reheating		Yes	
Hot serving	10	No	6
Serving packaging materials	11	No	7
Cool serving	12	No	8
Storage		Yes	
Receipt from kitchen		Yes	
Serving		Yes	

Table 8.5 Foods for which temperature control is required.

Kind of food	Details
• Cooked meat and fish and their products	• Prepared foods such as meat pies, fowl, cooked pork meats, fish products, pate and boiled meats
• Cooked meat in pasteurised tins	• Large packages of pork or pork shoulder
• Cooked vegetables	• Cereals, rice and legumes • Some cooked vegetables or desserts may have a high sugar concentration to prevent growth of pathogenic bacteria. These do not need to be temperature controlled
• Every cooked food that contains eggs or cheese	• Includes fruit flans and sweets
• Prepared salads and sauces	• Mayonnaise and prepared salads with mayonnaise or other sauces. Some salads or sauces might have such a composition (high acidity) to prevent the growth of pathogenic bacteria
• Soft cheeses/fermented cheeses	• Camembert, Brie, Stilton, Roquefort, Danish blue and other similar types
• Smoked fish or fresh molluscs	• Smoked salmon, smoked trout, smoked mackerel. Raw tuna, trout and other similar types
• Low-acidity desserts and cream products	• Includes desserts and dairy products, fresh cheeses and cakes with cream. Some creams might be stored at room temperature due to the low water activity or/and high sugar concentration. Suppliers should provide reasonable explanations
• Sandwiches that contain one of these products	• Snacks

Adapted from www.efet.gr.

Table 8.6 High-risk foods.

High-risk foods	Hazards	Critical control points	Monitoring
Foods manufactured on the spot • Sandwiches, pizza, cakes and salads, roasted chicken and other hot food *Cooked products* Containing meat, fish, eggs, cheese, cereals, cooked poultry and cold cooked meats; meat and fish pate; meat pie; vegetable pies *Cooked products destined for further processing before consumption* • Meat, fish or poultry pies, pizzas and ready-to-eat foods, partly cooked sausages. Fresh pasta with meat or fish *Smoked meats* • Cut in slices after smoking or salting, e.g. salami or other fermented sausages *Smoked fish* Whole pieces or cut in slices after smoking or salting, e.g. salmon, trout, mackerel, haddock and red herring *Dairy desserts* • Fresh cheeses, pudding, cream *Cheese* • Soft cheese or fermented Danish blue cheese, Camembert, Roquefort, Brie	*Microbiological contamination* Pathogenic bacteria and viruses could enter the foods or their ingredients, during handling, preparation and packaging, or after preparation, during distribution and storage. Bacteria could grow very fast in the foods if not in the fridge and cause disease when consumed. Alternatively, bacteria could be in a latent phase and cause poisoning only when the temperature of the product allows their growth at a further stage	*Microbiological contamination* 1. Temperature control during storage, distribution and display 2. Personnel training 3. Good hygiene practices 4. Appropriate shelf life to ensure microbiological safety and quality 5. Appropriate buildings and equipment 6. Fast distribution of frozen products at every distribution stage in the chain 7. Adequate cleaning to remove contamination areas 8. Additional protection measures where non-packaged products interfere 9. Pest control 10. Monitoring of temperature 11. Good waste disposal 12. Emergency procedures in case fridges are out of control *Physical contamination* 1. Display of non-packaged foods 2. Good product management to avoid contamination from personnel, buildings or environment 3. Good hygiene practices 4. Good cleaning systems to prevent contamination from cleaning procedures. Appropriate control of chemical disinfectants 5. Good pest control 6. Good waste disposal to avoid contamination 7. Trained personnel	Temperature control Instructions and/or training Personnel hygiene Product recycling Equipment Product handling Cleaning Display of non-packaged foods Pest control *Monitoring/records* Waste disposal Emergency procedures

(*Continues*)

Table 8.6 (*Continued*)

High-risk foods	Hazards	Critical control points	Monitoring
Ready-to-eat vegetables	*Physical contamination*	*Physical damage*	
• Including those containing fruits and rice	If manufactured food or its ingredients stayed uncovered during handling it is possible to for contamination to occur from foreign matter. Pieces of packaging materials, jewellery and hair could fall in the containers of food. Their presence could lead to serious damage or complaints *Physical damage* Damage in vacuum packaging, bags and protective packaging could give the chance to bacteria to contaminate or reduce the safety of the product or its shelf life	1. Right handling to avoid damage to the container or product 2. Pest control to avoid damage to the product or the container from pests 3. Trained personnel 4. Right placement of equipment and installation during storage to avoid damage of the product 5. Product recycling 6. Additional measures for non-packaged foods 7. Disposal procedure of damaged products	Installation Display of non-packaged products

Adapted from www.efet.gr.

development and improvement of materials prior to the onset of training.

The number of trays and the organisation of the staff who prepare them for serving influence the preparation time. Two systems were observed. In one case, all the trays were prepared and then reheated after their preparation by one person. In the other case, one person prepared the trays and another person reheated them one by one. The latter was more efficient, but required two people. It was noted that when the patient was not present for the meal, the tray was stored in the refrigerator of the local kitchen, but only after the distribution of all the other meals.

Holding food at temperatures outside the recommended range is an important and common error responsible for foodborne disease outbreaks. This study allowed them to follow up, for the first time in this hospital, the temperatures inside the food carts and inside the meals. Foods were maintained at appropriate temperatures in most cases. In the other cases, the errors responsible for this temperature increase were analysed and corrected.

These abnormalities may alter the food quality. Thus, it was important to compare the bacteriological status of the meals when they left the central kitchen and when the last patient was served. The increase in the total number of bacteria was probably due to the delay between opening the cart in the ward and the distribution of meals to patients, particularly in the summer when the ambient temperature in some countries (e.g. Mediterranean) can reach 30–35°C. The flow diagram of food businesses carrying out distribution of foods only is given in Fig. 8.2.

Reglier-Poupet *et al.* (2005) evaluated the quality of meals during transport from the kitchens to the patients in three departments of a university hospital. Meals were transported inside insulated, cooled food carts. They analysed the delays at each step of the transport process and measured the temperature inside the food cart and inside the meals. The total duration of the transport (mean = 85.3 minutes; range 44–123 minutes) conformed to the official recommendations (<2 hours at a temperature < 10°C before consumption). The internal temperature of 73.6% of the 30 food carts examined was below 10°C. The internal temperature of the meals was below 10°C in 91.7% of cases when the food cart was first opened, but in only 12% of cases by the time the last patient was served. No pathogens were isolated from any of the samples. However, 10% of meals, all of which were salads, had

Table 8.7 Medium-risk foods.

Medium-risk foods	Hazards	Critical control points	Monitoring
Hard cheeses Creamy cheeses Fresh cheeses Non-dairy products Unripened soft cheeses Smoked pieces of meat Fruit pies Raw meat and raw fish Sausages, bacon Fresh milk Vegetables Fruits	*Microbiological contamination* Growth of bacteria or moulds in the products. Growth might not be fast, however, safety and quality issues could reduce the shelf life. Bacteria could increase following thermal processing *Physical contamination* Could be caused by dirt, dust, loose packaging. Each non-packaged food should be protected from foreign matter falling on the product *Physical damage* Physical damage in the product or packaging could lead to deterioration of the product. The reasons are mechanical damage or storage in the wrong environment, e.g. increased humidity. Quality in fruits and vegetables could be affected by Melanisation	*Microbiological contamination* 1. Good hygiene practices to avoid the transfer of bacteria to foods 2. Temperature control when it is required during distribution, storage and display 3. Right handling to assure fast distribution under cooling conditions 4. Trained personnel 5. Product recycling to avoid microbial contamination beyond the shelf life 6. Adequate cleaning to remove contamination areas from bacteria 7. Pest control 8. Right equipment and installation to allow cleaning, and maintenance of correct temperatures 9. Additional measures where non-packaged foods interfere 10. Hygienic structure to avoid the presence of bacteria and dirt *Physical contamination* 1. Further requirements for display of non-packaged foods 2. Appropriate product management to avoid contamination from personnel, buildings and environment 3. Good hygiene practices from personnel to avoid contamination from hair, jewellery and clothes 4. Good pest control 5. Adequate standards of equipment and cleaning aids 6. Good cleaning systems to prevent cross-contamination 7. Trained personnel knowing the hazards and their prevention 8. Appropriate waste disposal and management to avoid contamination in foods for sale 9. Management of emergency procedures *Physical contamination* 1. Further requirements for display of foods without packaging 2. Appropriate waste management to prevent occurrence of diseases 3. Appropriate product management to avoid contamination from personnel, environment or buildings 4. Pest control 5. Product recycling to avoid contamination 6. Personnel aware of hazards and how to deal with them 7. Good structure and layout of buildings	Personnel hygiene Temperature control Product handling Instructions and/or training Product recycling Cleaning Pest control Equipment and installation Display of non-packaged foods Structure Display of non-packaged foods Product handling Equipment Cleaning Waste disposal Emergency procedures Instructions and/or training Display of non-packaged foods

Adapted from www.efet.gr.

Table 8.8 Low-risk foods.

Low-risk foods	Hazards	Critical control points	Monitoring
Foods preserved following thermal processing and packaging in hermetically sealed containers, such as canned foods, ready-to-eat foods with a long shelf life Dry vegetables Packaged soups Pickles Jams and marmalades Dry pasta products Dry mixtures of creams or dry mixes of drink preparations Chocolate sweets and other sweets Bread and biscuits Cakes and sweets (no added creams) Ice creams Frozen products	*Microbiological contamination* Most of these products are not suspect for food poisoning when they are under normal conditions. Yeasts and moulds could be developed if shelf life is not monitored *Physical contamination* Every open non-packaged product could be contaminated from packaging materials or other foreign matter during processing or display *Physical damage* Damage in the packaging of these products could form a point of microbiological or physical contamination. Bruised tins, torn packages could allow metal contamination or the appearance of stains. Improper storage in a cool or humid environment could modify physically the quality of the product	*Microbiological contamination* 1. Product recycling to ensure that quality and safety are achieved 2. Additional requirements where non-packaged products interfere 3. Personnel is aware of the hazards and how to deal with them 4. Pest control to avoid transfer of bacteria from insects/pests 5. Appropriate equipment for the correct monitoring of temperature in frozen foods *Physical contamination* 1. Further requirements for display of foods without packaging 2. Appropriate waste management to prevent occurrence of diseases 3. Appropriate product management to avoid contamination from personnel, environment or buildings 4. Pest control 5. Product recycling to avoid contamination 6. Personnel aware of the hazards and how to deal with them 7. Good structure and layout of buildings *Physical damage* 1. Appropriate handling to avoid damage of the container or product 2. Appropriate placement of equipment and installation during storage to avoid damage of the product 3. Additional measures for non-packaged foods 4. Personnel aware of the hazards and how to deal with them	Recycling of products Display of non-packaged foods Hygiene of personnel Instruction and/or training Pest control Temperature control Cleaning Management procedures Equipment and installation Product recycling Training Structure Management procedures Equipment and installation Instructions and/or training

Adapted from www.efet.gr.

total viable counts of bacteria above the recommended limits. This study confirmed that it is essential to control time and temperature to ensure food quality and safety in hospitals.

Most cases of food poisoning in hospitals result from shortcomings throughout the distribution chain rather than from the point of preparation, hence there needs to be an effective coordination between the professionals involved to ensure that food is appropriately controlled throughout its distribution and that safety controls are not compromised. Food hygiene training for those involved in the food chain, including non-food handlers, is a clear requirement (Reglier-Poupet *et al*. (2005).

The HACCP system was introduced to infant formula preparation rooms in four hospitals in Salvador, Bahia, Brazil, by Almeida *et al*. (1999). Infant formulas are liquids or reconstituted powders fed to infants and

Table 8.9 Preservation times for different foods.

S/n	Foods/Category	Storage conditions	Maximum storage time
1.	Mixed salads	Cooling (<5°C)	1 day
2.	Cheeses/dairy	Cooling (<5°C)	1 day
3.	Sausages	Cooling (<5°C)	1 day
4.	Cremes	Cooling (<5°C)	1 day
5.	Sauces	Cooling (<5°C)	4 days (no cream added), 2 days (cream or gravy added)
6.	Boiled eggs	Cooling (<5°C)	7 days (washing, cleaning, vinegar), 2 days (remainder)
7.	Omelette	Cooling (<5°C)	1 day
8.	Legumes	Cooling (<5°C)	1 day
9.	Cooked RTE foods	Cooling (<5°C)	2 days
10.	Cooked meat products	Cooling (<5°C)	2 days
11.	Minced meat	Cooling (<5°C)	2 days
12.	Chicken	Cooling (<5°C)	2 days
13.	Spaghetti, rice	Cooling (<5°C)	1 day
14.	Crackers, rusks	Dry storage	7 days
15.	Cakes (no syrup)	Cooling (<5°C)	2 days (cream added) 4 days (remainder)
16.	Sweets (room temperature)	Cooling (<5°C)	2 days (cream added) 4 days (syrup added)
17.	Tins (open)	Cooling (<5°C)	2 days
18.	Vegetables	Cooling (<5°C)	1 day
19.	Pies, pizza	Cooling (raw), freezing	3 days 2 months
20.	Fruits cut into pieces/natural juices	Cooling (<5°C)	
21.	Composts	Cooling (<5°C)	2 days
22.	Washed fruits non-peeled	Cooling (<5°C)	2 days
23.	Jellies, creams, rice pudding	Cooling (<5°C)	1 day
24.	Confectionery cream	Cooling (<5°C)	2 days
25.	Bread, other bakery products	Dry storage	1 day
26.	Soups/broth	Cooling (<5°C)	2 days

Adapted from www.efet.gr.

young children. They serve as substitutes for human milk. Prepared infant formula is primarily water and non-fat cow's milk. Among other ingredients, it may include sweeteners, such as lactose, corn syrup or other sugars and fats, such as coconut and soybean oils. Vitamin and mineral supplements are typically universal additions. A few brands contain mono- and diglycerides, emulsifiers that keep the liquid from separating.

The homogenisation of powdered milk and ingredients, refrigeration and holding steps before service were identified as CCPs. Utensils and workers' hands were identified as sources of cross-contamination. Educational training courses emphasising food safety and good preparation practices were introduced to the personnel of the formula preparation rooms. Corrective actions were adopted at the CCPs that were found to be out of control. Implementation of the HACCP system improved infant formula quality by reducing total aerobic microbial counts in the formula, and on utensils and workers' hands of approximately 4.0, 3.0 and 4.0 log cycles, respectively. *S. aureus* and faecal coliforms were no longer found.

Enterobacter sakazakii in infant milk formula (IMF) has been implicated in infant infections, especially among high-risk infants who are premature, have a low birth weight or are immunocompromised. Since IMF is not sterile, good hygienic practices (i.e. rehydration, cold storage and reheating) for its preparation and distribution to infants are crucial in order to prevent secondary contamination and multiplication. The purpose of the study by Rosset *et al.* (2007) was to assess the temperature conditions in neonatal

Table 8.10 Organoleptic and physicochemical characteristics and microbiological parameters for spices.

Raw material: Spices **Category: Seasonings and essential oils**		
Organoleptic characteristics	• State of packaging • State of purity of material • Labelling • Receipt temperature • Colour, texture, taste, odour	No bruises, no visible dirt Free from dirt and foreign matter Expiry date Room temperature
Physicochemical characteristics	• Moisture • Ash (depending on type) • Insoluble in hydrochloric acid in ash compounds (depending on type) • Toxic compounds (insecticides, pesticides) • Heavy metals (Pub, Hg, Cd, As, Sb) • Mycotoxins	15% max 2.5% max–7% max 0.6% max– 2% max Absence Absence Absence
Microbiological parameters	Micro-organisms	*B. cereus*, *Cl. botulinum*, *Salmonella* spp., *Cl. perfringens*, *St. aureus* (toxin)
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions	

Table 8.11 Organoleptic and physicochemical characteristics and microbiological parameters for salt.

Secondary raw material: Salt **Category: Seasoning agents and essential oils**		
Organoleptic characteristics	• State of packaging • State of purity of material • Labelling • Receipt temperature • Colour • Colouring agents • Taste–odour • Texture	No bruises, no visible dirt Free from dirt and foreign matter Expiry date Room temperature White–snow-white Absence Salty
Physicochemical characteristics	• Reaction in the presence of phenolphthalein • NaCl concentration • Insoluble compounds in water • Heavy metals (Pb, Hg, Cd, As, Sb) • Magnesium chloride • Insoluble substances in HCl 10% • Potassium fluoride	Neutral >97% <0.2% Absence <1% <0.8% ≤ 200 mg/kg
Microbiological parameters		
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions	
Notice	In the case of iodine salt, it should be mentioned that KI has been added at a concentration of 40–60 ppm	

Table 8.12 Organoleptic and physicochemical characteristics and microbiological parameters for vinegar.

Secondary raw material: Vinegar **Category: Seasoning agents and essential oils**		
Organoleptic characteristics	• State of packaging • State of purity of material	No leakages, no bruises, no visible dirt Clear solution, no dirt and foreign matter Absence of precipitate
	• Labelling • Receipt temperature • Taste • Acetic acid • Colour, odour	Expiry date Room temperature Acidic >6%
Physicochemical characteristics	• Precipitate • Toxic compounds • Colouring agents • Inorganic and organic compounds • Sulphates (SO_2^{2-})	Absence (transparent) Absence Absence (vinegar in wine) Absence except E150a, E150b, E150c, E150d <170 mg/L (vinegar following fermentation)
Microbiological parameters		
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions	

Table 8.13 Organoleptic and physicochemical characteristics and microbiological parameters for olive oil.

Secondary raw material: Olive oil **Category: Edible fats and oils**		
Organoleptic characteristics	• State of packaging • State of purity of material	No leakages, no bruises, no visible dirt Absence of foreign matter. Transparent at $T = 20^{\circ}C$
	• Labelling • Receipt temperature • Taste, odour	Expiry date Room temperature Acidic, absence of rancidity, decomposition or mould
Physicochemical characteristics	• Moisture and volatile compounds • Acidity • Soaps • Toxic compounds • Refractive index • Saponification number • Iodine number • Fe • Cu • Pb • As	≤ 0.2% 0–1° Absent (<0.005%) Absence 1.4677–1.4705 184–196 75–94 <5 mg/kg (virgin) <1.5 mg/kg (refined) <0.4 mg/kg (virgin) <0.1 mg/kg (refined) <0.1 mg/kg <0.1 mg/kg
Microbiological parameters	• Pathogenic micro-organisms	Absence
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions	

Table 8.14 Organoleptic and physicochemical characteristics and microbiological parameters for seed oil.

Secondary raw material: Seed oils **Category: Edible oils and fats**		
Organoleptic characteristics	• State of packaging	No leakages, no bruises, no visible dirt
	• Labelling	Expiry date
	• Receipt temperature	Room temperature
	• Odour–taste	Free from unpleasant odours and rancidity
	• Colour	Characteristic of the product
Physicochemical characteristics	• Acidity expressed as oleic acid	Virgin: max 2% except palm oil where max 5%; refined: max 0.3%
	• Peroxide number	Max 10 mg O_2/kg edible oil
	• Moisture and volatile compounds	Max 0.2%
	• Insoluble in petroleum ether substances	Max 0.05%
	• Soaps	Max 0.005%
	• Fe	Virgin: max 5 mg/kg; Refined: max 1.5 mg/kg
	• Cu	Virgin: max 0.4 mg/kg; Refined: max 0.1 mg/kg
	• Pb	Max 0.1 mg/kg
	• As	Max 0.1 mg/kg
Microbiological parameters		
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions	

Table 8.15 Organoleptic and physicochemical characteristics and microbiological parameters for margarine.

Secondary raw material: Margarine **Category: Edible oils and fats**		
Organoleptic characteristics	• State of packaging	No leakages, no bruises, no visible dirt
	• Labelling	Expiry date
	• Receipt temperature	$<4^{\circ}C$
	• Taste, odour, colour, texture	
Physicochemical characteristics	• Fatty acid concentration	>80%
	• Melting point	$<40^{\circ}C < 44^{\circ}C$ (confectioneries)
	• Acidity	$<5^{o}$
	• Chlorides	<0.2% (expressed in NaCl)
	• Fe	1.5 mg/kg
	• Cu	0.1 mg/kg
	• Pb	0.1 mg/kg
	• As	0.1 mg/kg
	• Sorbates acids (E200, E202, E203)	<1000 mg/kg <2000 mg/kg (fat <60%)
	• Soaps	<0.005%
Microbiological parameters		
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	(0–4°C)	

Table 8.16 Organoleptic and physicochemical characteristics and microbiological parameters for evaporated milk.

Raw material: Evaporated milk **Category: Milk, eggs and their products**		
Organoleptic characteristics	• State of packaging	Not bruised, flattened, no leakages and visible dirt
	• State of purity of materials	Absence of foreign matter
	• Labelling	Production and expiry date
	• Receipt temperature	Room temperature
	• Taste, odour, colour	
Physicochemical characteristics	• Toxic compounds (insecticides, antibiotics, pesticides)	Absence
	• Heavy metals	Absence
	• Sorbic compounds (E200, E202, E203)	<1000 mg/kg
Microbiological parameters	• *Salmonella* spp. (in 1 g)	Absence
	• Pathogenic micro-organisms	Negative
	• Total microbial count	Negative
	• Coliforms	Negative
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions. If opened, store in the fridge at (0–4°C)	

Table 8.17 Organoleptic and physicochemical characteristics and microbiological parameters for pasteurised UHT milk, milk cream and others.

Raw material: Pasteurised UHT milk, milk cream and others **Category: Milk, eggs and their products**		
Organoleptic characteristics	• State of packaging	Packaged product No leakages, no swelling, no visible dirt
	• State of purity of material	Absence of foreign matter
	• Labelling	Date of pasteurisation and use by date Description of type of milk
	• Receipt temperature (UHT at room temperature)	≤6°C
	• Foreign matter	Absence
	• Taste, odour, colour	
Physicochemical characteristics	• Peroxidase test	Positive (pasteurised)
	• Heavy metals	Absence
	• Pesticides, antibiotics, toxic metals	Absence
	• Negative phosphatase test	
Microbiological parameters	• *S. aureus* (in 1 mL)	<100
	• Pathogenic micro-organisms	Absence
	• Total microbial count (cfu/L)	$\leq 50 \times 10^3$
	• Coliforms (cfu/L) (E. *coli*, *Kleb. Enterobacter*)	≤10
	• *Salmonella* spp. (in 25 g)	Absence
	• Characteristic micro-organisms	*Yersinia enterocolitica*, *Tub. bacilli*, *Brucella abortus*, *B. melitensis*, *Salmonella* spp., *Campylobacter jejuni*, *Listeria monocytogenes*, *Shigella* spp., *St. aureus* (toxin), Norwalk viruses, Hepatitis A, *B. cereus*, *Cl. perfringens*
Packaging	Aseptic like TETRAPACK	
Shelf life	As indicated in the packaging	
Storage–maintenance conditions	(0–4°C)	

Table 8.18 Organoleptic and physicochemical characteristics and microbiological parameters for fresh eggs.

Raw materials: Fresh eggs **Category: Milk, eggs and their products**		
Organoleptic characteristics	• State of packaging	Visually controlled fresh eggs, uncracked, no cracks on the shell and not dirty
	• Labelling	'Use by date' Tape for visual control
	• Receipt temperature	Room temperature or maintenance at (<4°C)
Physicochemical characteristics	• Growth factors (hormones)	Absence
Microbiological parameters	• Pathogenic micro-organisms	Absence
	• Characteristic micro-organisms	*Salmonella* spp. *S. enteritidis*
Packaging	Cartons	
Shelf life	As indicated on the package	
Storage–maintenance conditions	0–4°C	

care units for the preparation and storage of IMF and infant feeding using bottles and continuous feeding syringes.

Enterobacter sakazakii in IMF for feeding infants was chosen as the subject of this study because of the high risk incurred by IMF manufacture without total microbial destruction and the high sensitivity and mortality rates of this population group. From IMF preparation until neonate feeding, time–temperature profiles of IMF samples were monitored and analysed. In order to show the health impact of this data, potential *E. sakazakii* growth was calculated. As IMF can be also contaminated with *Salmonella*, potential *Salmonella* growth was also calculated. However potential *E. sakazakii* growth data were only analysed because of *E. sakazakii* and *Salmonella* spp. data being close. The study of 25 neonatal care units in 15 hospitals showed that the final potential growth for bottles depended on different parameters: initial water temperature, room temperature where IMF was prepared,

Table 8.19 Organoleptic and physicochemical characteristics and microbiological parameters for bottled water.

Raw material: Bottled water, carbonated **Category: Drinks**		
Organoleptic characteristics	• State of packaging	No leakages, no visible dirt, no torn labels
	• Labelling	Bottling and expiry date
	• Receipt temperature	Room temperature
	• Taste, odour, colour	
Physicochemical characteristics	• Nitrates (N) (g/L)	≤10
	• Mercury (Hg) (g/L)	0.001 max
	• BOD 5 (g/L)	<1
	• TOC (g/L)	≤1
	• Trihalomethane (g/L)	0.1 max
	• Colouring agents	Absence
	• Toxic compounds (insecticides etc.)	Absence
Microbiological parameters	• Total number of aerobic bacteria	Stable number
	• Coliforms (cfu/mL)	<6/200
	• (*Faecal coliforms*) (cfu/mL)	Absence in 200 mL
	• Pathogenic micro-organisms (*Salmonella* spp., *Shigella* spp., *St. aureus*, *Pseudomonas*, *Cl. perfringens*)	Absence in 1 L
	• Characteristic micro-organisms	*Giardia lamblia* (parasites)
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry or refrigerated	

Table 8.20 Organoleptic and physicochemical characteristics and microbiological parameters for fresh meat and fresh poultry.

Raw material: Fresh meat – fresh poultry **Category: Meat and their products**		
Organoleptic characteristics	• State of packaging	Poultry with no neck, no viscera, no rims, type 70%
	• Labelling	Seal of veterinarian
	• State of purity	Free from dirt and foreign matter
	• Receipt temperature	No ice 7 or 12°C max
	• Foreign matter (wood, glass, plastic)	Absence
	• Odour, colour, texture	
Physicochemical characteristics	• Toxic compounds (insecticides, antibiotics, hormones, toxins, colouring agents, fertilisers, fungicides	Absence
	• Heavy metals	Absence
Microbiological parameters	• *Cl. perfringens* (cfu/g)	<10
	• *St. aureus* (cfu/g) *Salmonella* spp.	<100 Absence in 10 g
	• *E. coli* (cfu/g)	<50
	• Pathogenic micro-organisms	Absence
	• Total microbial count (cfu/g)	$<5 \times 10^5$
	• Characteristic micro-organisms	*Cl. putrefaciens*, *Enterobacter*, *E. coli* O157:H7, *Pseudomonas*, *St. aureus*, *B. cereus*, *Campylobacter jejuni*, *Cl. botulinum*, *Listeria monocytogenes*, *Salmonella* spp., *Yersinia enterocolitica*, *Cl. perfringens* Parasites (meat): *Toxoplasma gondii*, *Sarcocystis hominis*, *Sarcoccystis shihominis*, *Trichinella spiralis*, *Taenia*
Packaging		
Shelf life	3 days (refrigeration), 9 months (freezing)	
Storage and maintenance conditions	Refrigeration (0–4°C), freezing (<−18°C)	

cold storage temperature and time, reheating temperature and time. One parameter was not usually enough to determine the final growth increment alone, and a well-controlled and high performance stage could result in an incorrect food safety indication if the other stages are less effective. On the other hand, the final potential growth for the continuous feeding syringes depended mainly on the feeding period since the IMF was kept in a particularly high ambient air temperature (approximately 25°C) in the infant's bedroom. This stage would be controlled first (with a cold syringe cover, for example); then, as for bottles, the other stages would be controlled to result in a correct food safety indication (Rosset *et al.* (2007).

Bas *et al.* (2005) determined food safety practices related to PRP implementation in hospital food services in Turkey. Staff often lacked basic food hygiene knowledge. Problems of implementing HACCP and PRPs in hospitals included lack of food hygiene management training, lack of financial resources and inadequate equipment and environment. Time and temperature errors and inadequate hand washing are only two of the practices that were identified as problems in hospitals. Most hospital food services did not record food temperatures. Food thawing at room temperature was also commonly monitored. Hot or cold foods were not held at recommended temperatures. The number of hospitals using cook–chill or cook–freeze is not known, but by the late 1980s nearly 20% of UK hospitals used this system (Barrie, 1996). On 29 August 1996, Ireland's Eastern Health Board (EHB) was informed of an outbreak of gastrointestinal illness in a psychiatric hospital in Dublin. Fifty people among 240 members of staff and 183 patients had

Table 8.21 Organoleptic and physicochemical characteristics and microbiological parameters for frozen meat and frozen poultry.

Raw materials: Frozen meat – frozen poultry **Category: Meat and their products**		
Organoleptic characteristics	• Labelling	Name and address of the business, type of slaughter house, freezing date, seal of veterinarian Expiry date
	• Wrapping	Plastic material
	• State of purity	Free from dirt and foreign matter
	• Receipt temperature	–12°C max
	• Foreign matter (wood, glass, plastic)	Absence
	• Colour, texture	
Physicochemical characteristics	• pH	<6.5
	• Toxic compounds (insecticides, antibiotics, hormones, toxins, fertilisers, fungicides)	Absence
	• Heavy metals	Absence
Microbiological parameters	• *E. coli* (per 0.001 g product)	Absence
	• Pathogenic micro-organisms (*Cl. perfringens*, *Cl. botulinum*)	Absence
	• Total microbial count (cfu/g)	$<1 \times 10^6$
	• *Wel. perfringens* (0.1 g)	Absence
	• Characteristic micro-organisms	*Cl. perfringens*, *E. coli* O157:H7, *Cl. botulinum*, *Campylobacter* spp., *Cl. putrefaciens*, *Enterobacter*, *Pseudomonas*, *B. cereus*, *Listeria monocytogenes*, *Salmonella* spp., *Yersinia enterocolitica*, *Wel. perfringens*
Packaging		
Shelf life	9 months	
Storage–maintenance conditions	Freezing (< −18°C)	

reportedly fallen ill since 27 August and new cases were still occurring. The EHB immediately started an investigation to assess the extent of the outbreak, identify the mode and vehicle of transmission and initiate appropriate control measures (Grein *et al*., 1997).

8.8 AIRLINE FOOD CATERING COMPANIES

HACCP is also an established safety management system in civil aviation (Hatakka, 2000) and many airline catering companies use the global quality policy described by LSG-Hygiene Institute (1997). Bata *et al*. (2006) documented the time, the effort and resources devoted by an airline catering enterprise to improve the GHP (good hygiene practice) and to implement successfully the HACCP system and to report problems that were experienced during the total period of HACCP system adoption. Questionnaires also recorded the perception of the employees to the cost of the HACCP system. The study estimated the costs of development, implementation and operation of a HACCP and PRPs in an airline catering establishment. The development of the HACCP system was assigned to a consultant. The preparation of the company to install the system took place over a period of 5 years. The cost was greatly affected by the existing hygienic status and the size of the establishment, the complexity of the operation, the number and the experience of employees involved. In the initial stages, the implementation of the HACCP system required additional resources, technical support facilities and financial inputs to improve the GHP prerequisites. Investments were made in the purchase of temperature monitoring devices and other equipment to maintain raw materials and final prepared meals at proper temperatures. The total cost was divided into development (€23,017.25), installation

Table 8.22 Organoleptic and physicochemical characteristics and microbiological parameters for fresh molluscs.

Raw materials: Fresh molluscs **Category: Fish and their products**		
Organoleptic characteristics	• Squama	Should not have a dry and separated shell which opens with no resistance, soft flesh, rancid, and rancid fluids
	• Gastropods	Should not have a misty body and rancid taint
	• Echinoderm	Should not have spines which close, reddish fluids and unpleasant odour
	• State of packaging	Use by date (packaged product) No bruises, no visible dirt
	• Labelling • Receipt temperature • Foreign matter (plastic, wood, metal objects) Colour, texture	Use by date <2°C Absence
Physicochemical characteristics	• Toxins (paralytic PSP, *diarrhoea* DSP, *neurotoxin* NSP, *amnesiac* ASP)	Absence (PSP < 80 μg/100 g)
	• ABVT (total volatile nitrogen (in 100 g)	<25 mg
	• Heavy metals (Hg, Pb, Cd)	Absence (Hg <0.5 ppm)
Microbiological parameters	• *Total aerobic count* (in 1 g)	<10,000
	• *St. aureus* (in 1 g)	<100
	• *Escherichia coli* (in 1 g)	<10
	• *Coliforms*	<5/cm^3
	• Characteristic micro-organisms	*Vibrio parahaemolyticus*, *Aeromonas hydrophila*, *A. sobria*, *Proteus*, *Cl. botulinum*, *Shigella* spp., *St. aureus*, *Vibrio* spp., *Listeria monocytogenes*, *Campylobacter jejuni*, *Y. enterocolitica*, *E. coli*, *Salmonella* spp., Hepatitis A, Norwalk virus, Non A/Non B enteral hepatitis viruses *Parasites*: *Anisakis* spp., *Diphyllobothrium*, *Pseudoterranova*
Packaging		
Shelf life	1 day or consumption within the use by date	
Storage–maintenance conditions	<4°C	

(€108,693.41), certification cost (€6000.00) and operational–maintenance cost (€71,520.00). It was concluded that for every meal the cost of the system was an additional €0.01.

Following an outbreak of salmonellosis affecting 415 passengers on flights in 1991, the associated flight catering establishment located on a Greek island was surveyed for two years. During the first year of the survey, the bacteriological quality of food was not satisfactory. In an attempt to maximise food safety for crew and passengers, the HACCP approach was implemented in 1993. Since its application, greatly supported by the management and staff, the bacteriological quality of aircraft meals was considerably improved (Lambiri *et al*., 1995).

8.9 LEGISLATIVE REQUIREMENTS

The Australian Food Standard Code stipulates that all food service businesses must develop a HACCP-based food safety programme. Numerous other bodies around the world, the Canadian Code of Recommended Manufacturing Practices (Agriculture Canada, 1990), the US Food and Drug Administration (2001), the Advisory Committee on the Microbiological Safety of Food (1995), the European Chilled Food Federation Botulism Working Party (Gould, 1999) and the Food Linked Agro-Industrial Research European Commission (1997), address the food safety risks of long shelf life (LSL) cook–chill technologies including sous-vide and hot-fill.

Table 8.23 Organoleptic and physicochemical characteristics and microbiological parameters for frozen molluscs.

Raw materials: Frozen molluscs **Category: Fish and their products**		
Organoleptic characteristics	• Squama	Should not have a dry and separated shell which opens with no resistance, soft flesh, rancid and rancid fluids
	• Gastropods	Should not have a misty body and rancid taint
	• Echinoderm	Should not have spines which close, reddish fluids and unpleasant odour
	• State of packaging	Use by date, No bruises, no visible dirt
	• Labelling	Consumption date
	• Receipt temperature	<−15°C
	• Foreign matter	
	• Colour, texture	Absence
Physicochemical characteristics	• Toxins (paralytic PSP, *diarrhoea* DSP, *neurotoxin* NSP, *amnesiac* ASP)	Absence (PSP <80 μg/100 g)
	• ABVT (total volatile nitrogen (in 100 g)	<25 mg
	• Heavy metals (Hg, Pb, Cd)	Absence (Hg <0.5 ppm)
	• Sulphurous acid, acetic acid (E220, E223)	<0.1 g/kg fish
	• Colouring agents	Absence
Microbiological parameters	• *St. aureus* (in 1 g)	<100
	• *Escherichia coli* (in 1 g)	<10
	• Total anaerobes (in 1 g)	<10,000
	• Coliforms	<5/cm^3
	• Characteristic micro-organisms	*Vibrio parahaemolyticus*, *Aeromonas hydrophila*, *A. sobria*, *Proteus*, *Cl. botulinum*, *Shigella* spp., *St. aureus*, *Vibrio* spp., *Listeria monocytogenes*, *Campylobacter jejuni*, *Y. enterocolitica*, *E. coli*, *Salmonella* spp., Hepatitis virus A, Norwalk viruses, Non A/Non B enteral hepatitis viruses *Parasites*: *Anisakis* spp., *Diphyllobothrium*, *Pseudoterranova*
Packaging		
Shelf life	9 months or according to use by date	
Storage–maintenance conditions	Freezing (<−18°C)	

8.10 SCHOOL KITCHENS

The CCPs identified in the preparation of salads were the raw materials, the utensils used, the cutting implement and, above all, the sanitising agent used to wash the vegetables. Thus, in these school kitchens several controls were designed for raw materials, cold stores, freezers, active chlorine levels in water after sanitising and microbiological examination (Ehiri *et al*., 1995). When raw material was received, technical data were required concerning packaging materials and conditions, storage and distribution conditions (temperatures refrigerated or frozen), product structures and pack labelling.

Checking the temperature of supplied products has a practical value, since high-temperature fluctuations through the distribution system should be avoided.

Permissible levels of temperatures can be set as appropriate, for example frozen foods at –18°C (critical limit –14°C) and chilled foods at +5°C (critical limit +8°C) (Ehiri *et al*., 1995). Therefore, the starting point is to ensure that foodstuffs and ingredients are identified and documented. Products should be transported with vehicles appropriate to the product concerned and are maintained in clean and hygienic conditions.

Other CCPs are the temperatures and times of cooking, reheating and of cold and hot storage of foods.

Table 8.24 Organoleptic and physicochemical characteristics and microbiological parameters for ice creams.

Raw materials: Ice creams **Category: Products with sweeteners**		
Organoleptic characteristics	• State of packaging	Closed and protected individual packages or big packages
	• Labelling	Production and expiry date
	• Receipt temperature	Soft $<-12^{\circ}C$ Normal $<-18^{\circ}C$
Physicochemical characteristics	• Heavy metals (As, Pb, Zn, Cd)	Absence
	• Toxic compounds (pesticides, antibiotics, insecticides)	Absence
Microbiological parameters	• *Salmonella*/25 g	Absence
	• Total number of aerobic micro-organisms per gram	$<10 \times 10^4$ (with milk) $<30 \times 10^3$ (no milk)
	• Coliforms in 30°C/g	<10
	• Staphylococci/0.1 g	Absence
	• Phosphatase reaction	Negative
	• Characteristic micro-organisms	*Yersinia enterocolitica*, *Tub. bacilli*, *Brucella abortus*, *B. melitensis*, *Salmonella* spp., *Campylobacter jejuni*, *Listeria monocytogenes*, *Shigella* spp., *St. aureus* (toxin), viruses Norwalk, Hepatitis A, *B. cereus*, *Cl. perfringens*
Packaging		
Shelf life	As indicated on the label	
Storage–maintenance conditions	Freezing (soft ice cream $<-12^{\circ}C$, normal $<-20^{\circ}C$)	

Table 8.25 Organoleptic and physicochemical characteristics and microbiological parameters for frozen vegetables.

Raw material: Frozen vegetables **Category: Foods of plant origin**		
Organoleptic characteristics	• State of packaging	Sealed bags with no leakages in cartons, no visible dirt
	• Labelling	Packaging date and expiry date should be labelled
	• Receipt temperature	$<-18^{\circ}C$
Physicochemical characteristics	• Organoleptic characteristics	Following defrost organoleptic characteristics should be similar to those of fresh foods
	• Foreign matter (soil, stones, metal objects)	Absence
	• Toxic substances (pesticides, insecticides)	Absence
	• Heavy metals (Pb, Hg, Cd, As)	Absence
	• Colouring agents	Absence
Microbiological parameters	• Characteristic micro-organisms	Fungi, *Pseudomonas*, *Cl. botulinum*, *B. cereus*, *Listeria monocytogenes*, *Salmonella* spp., *Shigella* spp., *St. aureus* (toxin), Hepatitis virus A, Norwalk virus
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Freezing ($<-18^{\circ}C$)	

Table 8.26 Organoleptic and physicochemical characteristics and microbiological parameters for fresh food of plant origin.

Raw material: Fresh foods of plant origin (fruits, vegetables) **Category: Foods of plant origin**		
Organoleptic characteristics	State of product	Should be fresh, ripe, free of mud and pollution
	• Receipt temperature	Room temperature
Physicochemical characteristics	• Foreign matter (soil, stones, metallic objects)	Absence
	• Taste, odour, colour, texture	
	• Pesticide residues (parathion, malathion, arsenic and lead preparations)	Residues should not be detected
	• Mycotoxins (mainly in fruits)	Absence
	• Colouring agents (inorganic/organic)	Absence
	• SO_2	<50 mg/kg
Microbiological parameters	• Characteristic micro-organisms	*Vegetables*: Fungi, *Pseudomonas*, *Cl. botulinum*, *Listeria monocytogenes*, *B. cereus*, *Salmonella* spp., *Shigella* spp., *St. aureus* (toxin), Hepatitis A, Norwalk virus *Fruits*: Hepatitis A, Norwalk virus, *E. coli* O157:H7
Packaging		
Shelf life	≥ 15days (per case)	
Storage–maintenance conditions	<4°C and room temperature conditions (per case)	

Temperature control criteria for processes can be set and strictly adhered to; for example, all microbiologically sensitive foods should be cooked to an internal (geometric centre) temperature of at least 70°C for a given period of time (Bryan, 1981, 1992). Temperatures in chill rooms should be carefully monitored, preferably by an automatic recorder. All cold stores should be fitted with temperature chart recorders which must be recalibrated every 6 months (ICMSF, 1988). In addition to these, regular manual checks must also be undertaken.

Food production in four school kitchens was checked by Martinez-Tome *et al.* (2000) in order to improve the food safety by establishing a self-regulated

Table 8.27 Organoleptic and physicochemical characteristics and microbiological parameters for gum and vanilla.

Raw material: Gum/vanilla **Category: Natural extracts**		
Organoleptic characteristics	• State of packaging	No leakages, no bruises and visible dirt
	• Labelling	Expiry date
	• Receipt temperature	Room temperature
Physicochemical characteristics	• Odour, taste	
	• Mycotoxins (mainly *Aflatoxins*)	Absence
Microbiological parameters		
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions	

Table 8.28 Organoleptic and physicochemical characteristics and microbiological parameters for foods of plant origin concentrated and preserved in salt, vinegar, oil, ethyl alcohol and soups.

Raw material: Foods of plant origin concentrated and preserved in salt, vinegar, oil, ethyl alcohol and soups (mushrooms, olives, juices, tomato purees and similar products) **Category: Foods of plant origin**		
Organoleptic characteristics	• State of packaging	No leakages, no visible dirt, no spoilage (rust on the cork)
	• Labelling	Type and preservation material should be mentioned. Expiry date
	• Receipt temperature	Room temperature
Physicochemical characteristics	• Brine	Used for the first time
	• Organoleptic characteristics	Seeds should not present any spoilage
	• Foreign matter	Absence
	• Toxic substances (pesticides, insecticides)	Absence
	• Mycotoxins (non-pasteurised olives)	Absence
	• Colouring agents	Absence (olives, tomato paste)
	• SO_2	Absence (olives)
	• Salt	$\leq 12\%$
	• Alcoholic degree	$\geq 20\%$
Microbiological parameters	• Characteristic micro-organisms	Fungi (not in pasteurised olives), *Salmonella* spp. (olives)
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions	

Table 8.29 Organoleptic and physicochemical characteristics and microbiological parameters for legumes.

Raw material: Legumes **Category: Foods of plant origin**		
Organoleptic characteristics	• State of packaging	No leakages, no visible dirt, no spoilage
	• Labelling	Expiry date
	• Receipt temperature	Room temperature
Physicochemical characteristics	• Organoleptic characteristics	Present pleasant organoleptic characters. Natural colour, silky and unshrunk, free of any foreign mixing
	• During boiling with water	No change in organoleptic characteristics. Legumes boiled for longer than usual are considered of lower quality
	• Moisture and volatile compounds at 105°C	<14%
	• Infection by acari	<5%
	• Colouring agents	Absence
Microbiological parameters		
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions	

Table 8.30 Organoleptic and physicochemical characteristics and microbiological parameters for dry nuts.

Raw material: Dry nuts **Category: Foods of plant origin**		
Organoleptic characteristics	• State of packaging • Labelling • Receipt temperature	No visible dirt, insects Expiry date Room temperature
Physicochemical characteristics	• Organoleptic characteristics • Mycotoxins (*Aflatoxin*) • Toxic substances	Fresh, not broken, no spoilage Absence Absence
Microbiological parameters		
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions	

Table 8.31 Organoleptic and physicochemical characteristics and microbiological parameters for flour.

Raw material: Flour **Category: Cereals and their products**		
Organoleptic characteristics	• State of packaging	No leakages, no bruises and visible dirt, insects
	• Labelling • Receipt temperature	Expiry date Room temperature
Physicochemical characteristics	• Organoleptic characteristics • Contained gluten	No use of defective raw materials Cohesive, elastic ability to restrain water 62% min
	• Bran fineness (type 85%) • Acidity in sulphuric acid • Moisture • Gluten • Ash • Non-soluble in carbon tetrachloride • Fatty substances • Mycotoxins (mainly *Aflatoxin*)	>2% ≤0.08% max 13.5% max 26% min 0.5% max 0.015% max 1.10% max Absence
Microbiological parameters	• Characteristic micro-organisms	*B. cereus* *Salmonella* spp.
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions	

Table 8.32 Organoleptic and physicochemical characteristics and microbiological parameters for semolina.

Raw material: Semolina **Category: Cereals and their products**		
Organoleptic characteristics	• State of packaging • Labelling • Receipt temperature	No leakages, no bruises and visible dirt, insects Expiry date Room temperature or freezing $T < -18^{\circ}C$
Physicochemical characteristics	• Organoleptic characteristics • Origin • Moisture • Gluten • Ash • Acidity in sulphuric acid • Bran	Powdered form free of epicarp Wheat or maize 13.5 % max 26% min 0.80 % max 0.07% max 0.80% max
	Residues in carbon tetrachloride Mycotoxins (mainly *Aflatoxin*)	0.015% max Absence
Microbiological parameters	• Characteristic micro-organisms	*B. cereus* *Salmonella* spp.
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions or frozen ($T < -18^{\circ}C$)	

Table 8.33 Organoleptic and physicochemical characteristics and microbiological parameters for bread and bakery products.

Raw material: Bread – bakery products **Category: Cereals and their products**		
Organoleptic characteristics	• State of packaging	Free from foreign matter. In a paper bag or plastic bag
	• Labelling • Receipt temperature	Preparation and consumption date Room temperature or freezing temperature $< -18^{\circ}C$
Physicochemical characteristics	• Organoleptic characteristics	Uniform baking Uniform crust
	• Foreign matter (ropes, stones, parasites, insects)	Absence
	• Mycotoxins (mainly Aflatoxin)	Absence
	• Salt (NaCl)	$\leq 1.5\%$
	• Hop	Absence
	• Sorbic compounds E200, E202, E203	<2000 mg/kg
	• Colouring agents	Absence
Microbiological parameters	• Fungi • Mesenteric bacillus • Characteristic micro-organisms	Absence Absence *B. cereus*, *Salmonella* spp.
Packaging		
Shelf life	1 day or depending on the consumption date	
Storage–maintenance conditions	Cool and dry or freezing conditions ($T < -18^{\circ}C$)	

Table 8.34 Organoleptic and physicochemical characteristics and microbiological parameters for pasta products.

Raw material: Pasta products **Category: Cereals and their products**		
Organoleptic characteristics	• State of packaging • Labelling • Receipt temperature	No leakages, no bruises and visible dirt Expiry date Room temperature
Physicochemical characteristics	• Organoleptic characteristics • Odour, colour, taste • Moisture and volatile compounds at 105°C • Acidity • Ash • Mycotoxins (mainly *Aflatoxin*) • Colouring agents, preservatives	Not infected by worms or acari 12.5% max (summer period), 13.5% max (winter time) 10° max or 0.9% in lactic acid 0.80% max Absence Absence
Microbiological parameters		
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions	

Table 8.35 Organoleptic and physicochemical characteristics and microbiological parameters for cooked pork meat products.

Raw material: Cooked pork meat products **Category: Meat and their products**		
Organoleptic characteristics	• State of packaging	Container that blocks contact with the exterior environment
	• Labelling • Receipt temperature	Expiry date –2 to 2°C
Physicochemical characteristics	• Moisture • Taste, odour, colour, texture • Toxic substances	It depends on packaging materials Absence
Microbiological parameters	• *E. coli* (in 1 g) • *S. aureus* (in 1 g) • *Salmonella* spp. (in 1 g) • Characteristic micro-organisms	$<5 \times 10^2$ $<5 \times 10^2$ Absence *Lactobacillus*, *Streptococcus*, *Vibrio* spp., *Acinetobacter*, *Aspergillus* spp. (models), *Listeria monocytogenes*, *E. coli* O157:H7, *Salmonella* spp., *St. aureus*, *Cl. botulinum*, *Cl. perfringens*
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	0–4°C	

Table 8.36 Organoleptic and physicochemical characteristics and microbiological parameters for drinks free of alcohol and juices.

Raw material: Drinks free of alcohol – juices (concentrated and non-concentrated) – fillings for sweets **Category: Drinks**		
Organoleptic characteristics	• State of packaging • Labelling • Receipt temperature	No leakages, no bruises and visible dirt Expiry date Room temperature
Physicochemical characteristics	• Sweetener • Acidity (expressed as citric acid) • Specific gravity • Mycotoxins (mainly *Aflatoxin* and *patulin*) (for apple juice)	7 g/100 cm^3 min 0.10 g/100 cm^3 min 1.028 min at 15°C Absence
Microbiological parameters		
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions. Refrigeration at 0–6°C	

Table 8.37 Organoleptic and physicochemical characteristics and microbiological parameters for rice.

Raw material: Rice **Category: Cereals and their products**		
Organoleptic characteristics	State of packaging Foreign matter (stones, dust, splinters from straw)	No leakages, no bruises and visible dirt Absence
	• Labelling • Receipt temperature	Expiry date Room temperature
Physicochemical characteristics	• Organoleptic characteristics	Odour and spillage absence. No infection from insects or acari
	• Whitened • Moisture	Fully 16% max
	• Grain splinters • Yellow or yellowish grains (except parboiling) • Red or reddish • Greenish or cretaceous	<5% <0.5% <3% <2%
Microbiological parameters	Characteristic micro-organisms	*Bacillus cereus*
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions	

Table 8.38 Organoleptic and physicochemical characteristics and microbiological parameters for jams, halvas, gels and biscuits.

Raw material: Jams, halvas, gels, biscuits, doughnut **Category: Products with sweeteners**		
Organoleptic characteristics	• State of packaging • Labelling • Receipt temperature	No leakages, no bruises, no visible dirt Expiry date, percentage of sugar Room temperature
Physicochemical characteristics	• Foreign matter • Taste, odour	Absence
	• Toxic substances	Absence
Microbiological parameters	• Characteristic micro-organisms	*Salmonella* spp., *St. aureus*, *B. cereus*
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions	

Table 8.39 Organoleptic and physicochemical characteristics and microbiological parameters for mayonnaise.

Raw material: Mayonnaise **Category: Seasoning agents and essential oils**		
Organoleptic characteristics	• State of packaging • Labelling • Receipt temperature	No leakages, no visible bruises and dirt Expiry date Room temperature
Physicochemical characteristics	• Organoleptic characteristics • pH • Toxic substances	No use of deteriorated raw materials <4.5 Absence
Microbiological parameters	• Pathogenic micro-organisms • Characteristic micro-organisms	Absence *E. coli* O157:H7, *Salmonella* spp., *Cl. botulinum*, *Cl. perfringens*, *B. cereus*
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	0–4°C	

Table 8.40 Organoleptic and physicochemical characteristics and microbiological parameters for sugar.

Raw material: Sugar **Category: Sweeteners**		
Organoleptic characteristics	• State of packaging • Labelling • Receipt temperature	No leakages, no visible dirt, no spillage Expiry date Room temperature
Physicochemical characteristics	• Hue • Saccharose • Invert sugar • SO_2 produced • Colour, texture • Fermentation or spoilage • Foreign inorganic or organic substances • Colouring agents	12° max 99.7% min 0.04% w/w 10 mg/kg max Absence Absence Absence
Microbiological parameters		
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions	

Table 8.41 Organoleptic and physicochemical characteristics and microbiological parameters for yoghurt and yoghurt desserts.

Raw material: Yoghurt and yoghurt desserts **Category: Milk, eggs and their products**		
Organoleptic characteristics	• State of packaging	No bruises, no visible dirt. Container should be covered by waterproof paper or another permissible material
	• Mass condition	Compact, non-porous, surface should look like alabaster
	• Labelling	Expiry date
	• Receipt temperature	0–2°C
Physicochemical characteristics	• pH	Acidic
	• Organoleptic characteristics	Normal
	• Precipitate	Absence
	• Preservatives	Absence
	• Dyes	Absence of dyes
	• Sugar	Absence
Microbiological parameters	• *Salmonella* spp. (in 1 g)	Absence
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	0–4°C	

Table 8.42 Organoleptic and physicochemical characteristics and microbiological parameters for very hard cheeses.

Raw material: Very hard cheeses **Category: Milk, eggs and their products**		
Organoleptic characteristics	• State of packaging	No visible dirt
	• Receipt temperature	0–2°C
	• Labelling	Production and expiry date
Physicochemical characteristics	• Foreign matter (acari, worms, pupa or insects)	Absence
	• Moisture	32% max
	Organoleptic characteristics	No spoilage or loss of organoleptic characteristics (sour, rancid, unsavoury)
	• Toxins	Absence
	• Toxic or carcinogenic inorganic compounds	Not to exceed permissible limits
	• Silicates	<10 g/kg
	• Sorbic compounds	<2000 mg/kg
	• Niacin	<12.5 mg/kg
	• Colouring agents, preservatives, antibiotics	Absence
Microbiological parameters	• Salmonella spp. (in 1 g)	Absence
	• Pathogenic micro-organisms	Absence
	• Decomposition, fungi	Absence
	• Characteristic micro-organisms	*E. coli* O157:H7, *Listeria monocytogenes*, *St. aureus*, *Salmonella* spp.
Packaging		
Shelf life	≥2 months	
Storage–maintenance conditions	0–4°C	

Table 8.43 Organoleptic and physicochemical characteristics and microbiological parameters for hard cheeses.

Raw material: Hard cheeses **Category: Milk, eggs and their products**		
Organoleptic characteristics	• State of packaging	No visible dirt
	• Receipt temperature	0–2°C
	• Labelling	Production and expiry date
Physicochemical characteristics	• Foreign matter (acari, worms, pupa or insects)	Absence
	• Moisture	38% max
	Organoleptic characteristics	No loss of organoleptic characteristics (sour, rancid, unsavoury)
	• Toxins	Absence
	• Toxic or carcinogenic inorganic substances	Not to exceed permissible limits
	• Silicates	<10 g/kg
	• Sorbic compounds	<2000 mg/kg
	• Niacin	<12.5 mg/kg
	• Colouring agents, preservatives, antibiotics	Absence
Microbiological parameters	• *Salmonella* spp. (in 1 g)	Absence
	• Pathogenic micro-organisms	Absence
	• Decomposition, mould	Absence
	• Characteristic micro-organisms	*E. coli* O157:H7, *Listeria monocytogenes*, *St. aureus*, *Salmonella* spp.
Packaging		
Shelf life	≥2 months	
Storage–maintenance conditions	0–4°C	

control system based on GMPs and as an introduction to HACCPs. A form, which referred to different aspects such as the cleanliness of the installations, personnel hygiene and the prevention of cross-contamination, was used to obtain the necessary data.

They also designed several controls for raw materials, cold storage, freezers and available chlorine levels in water. At the end of the study period, they observed a decrease in microbial populations of examined samples, which indicated that the knowledge of hygiene practices on the part of food handlers represents a CCP.

8.11 FAST FOOD CONCEPTS

The slowing down of the rapid expansion of the standardised fast food/standardised service concepts may imply an emerging market saturation of these operations (Ogaard *et al.*, 2005). Competitiveness is thus increasingly dependent on the ability of suppliers to display the 'best practice' in all facets of their operations and segment and tailor their products to local variations in taste and preferences (Dwyer *et al.*, 2000).

Local adaptation, customisation and innovation will probably be needed much more, also within the multi-outlet operations. Even the epitome of extreme standardisation, McDonald's, adapts to local societal habits, that is they adjust the menu to include fish in some countries, e.g. the 'McFisk' in Norway and fish sandwiches in Hong Kong, beer and frankfurters in Germany and McSpaghetti in the Philippines, but they also adjust the production process to receive 'halal' ('clean', 'acceptable') certificates in Muslim countries (Ogaard *et al.*, 2005; Watson, 1997).

Ogaard *et al.* (2005) explored the relationship between organisational culture and the performance of managers in the restaurant industry. They also introduced the managers' job efficacy and commitment to the organisation as variables intervening between organisational culture and performance. Data were collected in a restaurant/fast food operation which included franchisees as well as employed managers. Results suggested that there are relationships between culture and manager's efficacy and organisational commitment, and that some cultural aspects are related to performance variables such as personnel cost

Table 8.44 Organoleptic and physicochemical characteristics and microbiological parameters for semi-hard cheeses.

Raw material: Semi-hard cheeses **Category: Milk, eggs and their products**		
Organoleptic characteristics	• State of packaging	No visible dirt
	• Receipt temperature	0–2°C
	• Labelling	Production and expiry date
Physicochemical characteristics	• Foreign matter (acari, worms, pupa or insects)	Absence
	• Moisture	46% max
	• Organoleptic characteristics	No main spoilage or loss of organoleptic characteristics (such as sour, rancid, unsavoury)
	• Toxins	Absence
	• Toxic or carcinogenic inorganic compounds	Should not exceed the permissible limits
	• Silicates	<10 g/kg
	• Sorbic compounds	<2000 mg/kg
	• Niacin	<12.5 mg/kg
	• Colouring agents, preservatives, antibiotics	Absence
	• E252 ($NaNO_2$)	<50 mg/kg
Microbiological parameters	• *Listeria monocytogenes* (in 25 g)	Absence
	• *Salmonella* spp. in 1 g	Absence
	• Pathogenic micro-organisms	Absence
	• Decomposition, mould	Absence
	• Characteristic micro-organisms	*E. coli* O157:H7, *Listeria monocytogenes*, *St. αureus*, *Salmonella* spp.
Packaging		
Shelf life	≥2 months	
Storage–maintenance conditions	0–4°C	

and additional sales. In addition, managers' commitment and efficacy are also related to performance. The flow diagram of food businesses which receive, maintain, prepare, process and sell food inside the business is given in Fig. 8.3.

8.12 GENERAL PRACTICES FOLLOWED BY CATERING ESTABLISHMENTS

The flow diagram of food businesses that do not prepare but process and sell food inside the business is shown in Fig. 8.4, and two flow diagrams of food businesses that receive, maintain, prepare, process but do not sell food inside the business but distribute unpackaged foods to other businesses and food are given in Figs. 8.5 and 8.6. In Table 8.3, the HACCP plan for catering is shown and the comparative presentation of CCPs of HACCP and ISO 22000 in conjunction with PRPs for catering is given in Table 8.4.

8.12.1 Cook–chill and cook–freeze catering

The food is fully cooked in a central food production unit which may be either off- or on-site. All stages from cooking to consumption are subject to strict temperature and time controls. The temperature at the geometrical centre of the food must be maintained at 70°C, for at least two minutes during cooking. In a cook–chill system, chilling should commence within 30 minutes of cooking and the temperature allowed to fall to 0°C to +3°C within 90 minutes. The food is transported at low temperature to the hospital kitchen where it is plated out. During transport and storage, food should be kept at <3°C. The maximum shelf life of cook–chill food is five days, including the day of cooking and the day of consumption, provided the temperature during storage remains at <3°C until reheating. If the temperature rises, the food may have to be consumed within 12 hours or discarded. The recommended storage temperatures must be rigorously adhered to in order to minimise bacterial growth.

Table 8.45 Organoleptic and physicochemical characteristics and microbiological parameters for soft cheeses.

Raw material: Soft cheeses **Category: Milk and their products**		
Organoleptic characteristics	• Cheese mass	Compact texture, with no or very little gaps White colour or whitish
	• Taste	Slightly acidic, salty, or slight taste of lipolysis
	• State of packaging	No visible dirt
	• Receipt temperature	0–2°C
Physicochemical characteristics	• Foreign matter (acari, worms, pupa or insects)	Absence
	• Moisture	58% max
	• Organoleptic characteristics	No main spoilage, no loss of organoleptic characteristics (such as sour, rancid, unsavoury)
	• Toxins	Absence
	• Toxic or carcinogenic inorganic compounds	Should not exceed the permissible levels
	• Silicates	<10 g/kg
	• Sorbic compounds	<2000 mg/kg
	• Niacin	<12.5 mg/kg
	• Colouring agents, preservatives, antibiotics	Absence
	• E252 (in $NaNO_2$)	<50 mg/kg
Microbiological parameters	• *Salmonella* spp. (in 1 g)	Absence
	• *S. aureus* (in 1 g or L)	<100
	• E. *coli* (in 1 g or L)	<100
	• Coliforms (at 30°C) (in 1 g or L)	<10,000
	• Pathogenic micro-organisms	Absence
	• Decomposition, mould	Absence
	• Characteristic micro-organisms	*E. coli* O157:H7, *Listeria monocytogenes*, *St. aureus*, *Salmonella* spp.
Packaging		
Shelf life	≥2 months	
Storage–maintenance conditions	0–4°C	

In the cook–freeze system, food is prepared and cooked, then freezing must commence within 30 minutes. The temperature must reach −5°C within 90 minutes and −18°C for storage. The food may need transporting and must be kept frozen until thawed to chill before plating out. Thawed cook–freeze food must be held at 6°C (and never exceed 10°C) until reheated and consumed within 24 hours of thawing. The shelf life of the frozen food is generally up to eight weeks.

Reheating chilled or thawed food should commence as soon as possible, always approximately 30 minutes after the food is removed from chill. The temperature should be controlled to achieve 70°C in the centre of the food and be maintained at 70°C for two minutes. Food to be eaten hot must be served within 15 minutes of reheating. This generally means that the food has to be reheated in clinical areas (i.e. as close as possible to the point of consumption) and not in the main kitchen (Barrie, 1996).

8.12.2 Boxed food

Boxed food is a convenient means of food supply when tourists are on the road. It always consisted of rice, meat (e.g. pork or chicken) and three or four kinds of vegetables in a meal box in Taiwan. This food service not only can save time but also avoid missing meal time while on a tour schedule. Most mass tourism in Taiwan uses boxed food for lunch, especially when tourists are travelling to the next destination.

Table 8.46 Organoleptic and physicochemical characteristics and microbiological parameters for frozen fish.

Raw material: Frozen fish (headless or not, cleaned or not) **Category: Fish and their products**		
Organoleptic characteristics	• State of packaging • Receipt temperature • Labelling	No bruises, no visible dirt <−18° C Use by date
Physicochemical characteristics	• Foreign matter (plastic, wood, metallic objects) • Odour, texture	Absence
	• Heavy metals (Hg, Pb, Cd) • ABVT (total basic volatile <25 mg nitrogen in 100 g)	(Hg <0.5 ppm) <25 mg
Microbiological parameters	• Characteristic micro-organisms	*Acinetobacter*, *Proteus*, *Pseudomonas*, *Vibrio* spp., *Salmonella* spp., *Campylobacter jejuni*, *Cl. botulinum*, *Shigella* spp., *St. aureus*, *Enterobacteriaceae*, *L. monocytogenes*, *E. coli Parasites*: *Anisakis* spp., *Diphyllobothrium*, *Pseudoterranova*
Packaging		
Shelf life	Freezing: 9 months depending on the consumption date	
Storage–maintenance conditions	Freezing (<−18°C)	

Table 8.47 Organoleptic and physicochemical characteristics and microbiological parameters for fresh fish.

Raw material: Fresh fish (headless or not, cleaned or not) **Category: Fish and their products**		
Organoleptic characteristics	• State of packaging • Receipt temperature • Labelling • State of packaging	No bruises, no visible dirt <2°C Depending on the packaging Use by date
Physicochemical characteristics	• Foreign matter (plastic, wood, metal objects) • Odour, texture	Absence
	• Heavy metals (e.g. Hg, Pb, Cd) • ABVT (total basic volatile <25 mg nitrogen in 100 g)	(Hg <0.5 ppm) <25 mg
Microbiological parameters	• Characteristic micro-organisms	*Acinetobacter*, *Proteus*, *Pseudomonas*, *Vibrio* spp., *Salmonella* spp., *Campylobacter jejuni*, *Cl. botulinum*, *Shigella* spp., *St. aureus*, *Enterobacteriaceae*, *L. monocytogenes*, *E. coli Parasites*: *Anisakis* spp., *Diphyllobothriums*, *Pseudoterranova*
Packaging		
Shelf life	2 days storage for those with no use by date	
Storage–maintenance conditions	0–4°C	

Table 8.48 Organoleptic and physicochemical characteristics and microbiological parameters for honey.

Raw material: Honey **Category: Sweeteners**		
Organoleptic characteristics	• State of packaging • Labelling • Receipt temperature	No leakages, no visible dirt and bruises Net weight, manufacturer's address Room temperature
Physicochemical characteristics	• Organoleptic characteristics	No foreign taste or odour. Not starting to ferment
	• Total sugar • Sugarcane • Ash • Foreign matter such as insects, sandy grains	60% min 10% max 1% max Absence
	• Antibiotic residues • Phenolic residues, parasiticides • Metal residues	Absence Absence Absence
Microbiological parameters	• Mould • Characteristic micro-organisms	Absence *Cl. botulinum*
Packaging		
Shelf life	As indicated on the packaging	
Storage–maintenance conditions	Cool and dry conditions	

Table 8.49 Organoleptic and physicochemical characteristics and microbiological parameters for sugar substitute.

Raw material: Sugar substitute **Category: Sweeteners**		
Organoleptic characteristics	• State of packaging • Labelling • Receipt temperature	No leakages, no visible dirt Expiry date Room temperature
Physicochemical characteristics	• Purity	
	• Taste	Sweet
	• Concentration in Pb, As, Hg	As in the regulations
Microbiological parameters	• Micro-organisms	
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions	

Table 8.50 Organoleptic and physicochemical characteristics and microbiological parameters for tea and coffee.

Raw material: Tea and coffee **Category: Coffee, tea, cocoa and their products**		
Organoleptic characteristics	• State of packaging • Labelling • Receipt temperature	No leakages, no visible dirt and bruises Expiry date Room temperature
Physicochemical characteristics	• Organoleptic characteristics	Not spoiled due to charring
	• Foreign matter (shell residues, small pieces of wood)	Absence
	• Moisture and volatile compounds at 105°C	5% max (coffee) 10% max (tea)
	• Water soluble materials	23% max (coffee) 30% max (tea)
	• Toxic substances • Pesticide residues, mycotoxins • Heavy metals	Absence Absence Absence
Microbiological parameters		
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions	

Table 8.51 Organoleptic and physicochemical characteristics and microbiological parameters for cocoa and chocolate.

Raw material: Cocoa, chocolate **Category: Coffee, tea, cocoa and their products**		
Organoleptic characteristics	• State of packaging • Labelling • Receipt temperature	No leakages, no visible dirt and bruises Expiry date Room temperature
Physicochemical characteristics	• Foreign matter (shell residues, small pieces of wood) • Odour, taste, colour • Toxic substances	Absence Absence
Microbiological parameters	• *Salmonella* spp. (in 1 g) • Characteristic micro-organisms	Absence *Salmonella* spp., *St. aureus*, *B. cereus*
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions	

Table 8.52 Organoleptic and physicochemical characteristics and microbiological parameters for chocolate, pastry sweet products, confectionery cream and various sweets with milk.

Raw material: Chocolate, pastry sweet products, confectionery cream, various sweets with milk **Category: Products with sweeteners**		
Organoleptic characteristics	• State of packaging • Labelling • Receipt temperature	No leakages, no bruises, no visible dirt Expiry date <−18°C
Physicochemical characteristics	• Foreign matter • Colour, texture • Toxic substances • Mycotoxins (mainly Aflatoxin)	Absence Absence Absence
Microbiological parameters	• *Salmonella* spp. (in 1 g) • *S. aureus* (in 1 g or L) • *E. coli* (in 1 g or L) • Characteristic micro-organisms	Absence <100 <100 *Salmonella* spp., *S. aureus*, *B. cereus*, *Listeria monocytogenes*, *E. coli* O157:H7, *Vibrio* spp., *Streptococcus*, *Aspergillus* spp. (models), *Cl. botulinum*, *C. perfringens*
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Freezing (<−18°C)	

Table 8.53 Organoleptic and physicochemical characteristics and microbiological parameters for animal fat.

Raw material: Animal fat **Category: Edible oils and fats**		
Organoleptic characteristics	• State of packaging	No leakages, no bruises, no visible dirt
Physicochemical characteristics	• Labelling	Origin should be clear
	• Labelling	Expiry date
	• Receipt temperature	Room temperature
	• Melting point	Max 42°C (raw material) Max 44°C (cooking fat)
	• Odour, colour	
	• Acidity	Max 5
Microbiological parameters		
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions	

Table 8.54 Organoleptic and physicochemical characteristics and microbiological parameters for alcoholic drinks.

Raw material: Alcoholic drinks **Category: Various drinks**		
Organoleptic characteristics	• State of packaging	No leakages, no bruises and visible dirt
Physicochemical characteristics	• State of purity of material	Macroscopically should not present visible precipitate
	• Receipt temperature	Room temperature
	• Organoleptic characteristics	Pleasant taste and odour, normal characteristics
	• Toxic substances	Absence
	• Heavy metals	Absence
Microbiological parameters		
Packaging		
Shelf life		
Storage–maintenance conditions	Cool and dry conditions	

Table 8.55 Organoleptic and physicochemical characteristics and microbiological parameters for preservatives, raising agents and improvement agents.

Raw material: Preservatives – raising agents – improvement agents **Category: Food additives**		
Organoleptic characteristics	• State of packaging	No leakages, no visible dirt
Physicochemical characteristics	• Labelling	Minimum consumption date. Number of approval and 'food grade'
	• Receipt temperature	Room temperature
	• Purity	As described in the legislation
	• Concentration in Pb, As, Hg	As described in the legislation
	• Micro-organisms	As described in the legislation
Microbiological parameters		
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry place	

Table 8.56 Organoleptic and physicochemical characteristics and microbiological parameters for pastry products.

Raw material: Pastry products (salty) **Category: Cereals and their products**		
Organoleptic characteristics	• State of packaging • Labelling • Receipt temperature	No leakages, no bruises, no visible dirt Expiry date <−18°C
Physicochemical characteristics	• Foreign matter • Colour, texture	Absence
	• Toxic substances • Mycotoxins (mainly Aflatoxin)	Absence Absence
Microbiological parameters	• Pathogenic micro-organisms • Decomposition, mould • Characteristic micro-organisms	Absence Absence *Salmonella* spp., *St. aureus*, *B. cereus* *Listeria monocytogenes*, *E. coli* O157:H7, *Vibrio* spp., *Streptococcus*, *Aspergillus* spp. (models), *Cl.* *botulinum*, *Cl. perfringens*, *S. enteritidis*, Fungi, *Pseudomonas*, *Shigella* spp., Hepatitis A virus, Norwalk virus, *Lactobacillus*, *Acinetobacter*
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Freezing (–18°C)	

Table 8.57 Organoleptic and physicochemical characteristics and microbiological parameters for crust leaf, kataifi and pastry products.

Raw material: Crust leaf, kataifi, pastry products **Category: Cereals and their products**		
Organoleptic characteristics	• State of packaging • Labelling • Receipt temperature	No leakages, no bruises, no visible dirt Expiry date <−18°C
Physicochemical characteristics	• Foreign matter • Colour, texture	Absence
	• Toxic substances • Mycotoxins (mainly Aflatoxin)	Absence Absence
Microbiological parameters	• Mould • Bacilli • Characteristic micro-organisms	Absence Absence *Salmonella* spp., *S. aureus*, *B. cereus*, *Listeria monocytogenes*, *E. coli* O157:H7, *Vibrio* spp., *Streptococcus*, *Aspergillus* spp. (models), *Cl.* *botulinum*, *Cl. perfringens*
Packaging		
Shelf life	As indicated on the packaging	
Storage–maintenance conditions	Freezing (<−18°C)	

Table 8.58 Organoleptic and physicochemical characteristics and microbiological parameters for vegetable cream.

Raw material: Vegetable cream **Category: Products with sweeteners**		
Organoleptic characteristics	• State of packaging • Labelling • Receipt temperature	No leakages, no visible dirt, no spoilage Expiry date Room temperature
Physicochemical characteristics	• Organoleptic properties • Concentration in Pb, As, Hg	Pleasant taste and odour, normal organoleptic characteristics
Microbiological parameters	• Characteristic micro-organisms	TMC, *Coliforms*, *Faecal coliform*, *Salmonella* spp., *Shigella* spp., *St. aureus*, *Pseudomonas*, *Cl. perfringens*, *Giardia lamblia*
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions		

Table 8.59 Organoleptic and physicochemical characteristics and microbiological parameters for Canned tuna.

Raw material: Canned tuna **Category: Fish and their products**		
Organoleptic characteristics	• State of packaging	No leakages, no expansion, no visible dirt, no deterioration (rust on the package)
	• Labelling	Preservation material should be indicated. Expiry date
	• Receipt temperature	Room temperature
	• Foreign matter (plastic, wood, metal)	Absence
Physicochemical characteristics	• Brine • Heavy metals (Hg, Pb, Cd) • ABVT (total volatile nitrogen in 100 g)	 (Hg <0.5 ppm) <25 g
Microbiological parameters	• Characteristic micro-organisms	*Acinetobacter*, *Proteus*, *Pseudomonas*, *Vibrio* spp., *Salmonella* spp., *Campylobacter jejuni*, *Cl. botulinum*, *Shigella* spp., *St. aureus*, *Enterobacteriaceae*, *L. monocytogenes*, *E. coli Parasites*: *Anisakis* spp., *Diphyllobothrium*, *Pseudoterranova*
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions	

Table 8.60 Organoleptic and physicochemical characteristics and microbiological parameters for powdered cream.

Raw material: Powdered cream **Category: Milk, eggs and their products**		
Organoleptic characteristics	• State of packaging	No leakages, no expansion, no visible dirt
	• Purity state of material	Absence of foreign matter
	• Labelling	Expiry date. Type of milk
	• Receipt temperature	Room temperature
Physicochemical characteristics	• Foreign matter	Absence
	• Taste, odour, colour	
	• Heavy metals	Absence
	• Insecticides, antibiotics, toxic metals	Absence
Microbiological parameters	• Characteristic micro-organisms	*Yersinia enterocolitica*, *Tub. bacilli*, *Brucella abortus*, *B. melitensis*, *Salmonella* spp., *Pseudomonas*, *Campylobacter jejuni*, *Listeria monocytogenes*, *Shigella* spp., *St. aureus* (toxin), Norwalk viruses, Hepatitis A virus, *B. cereus*, *Cl. perfringens*, *Giardia lamblia*
Packaging	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions	

In addition, tourists enjoy eating boxed food on the railway and it has become an important tourism image of railway tourism in Taiwan, called 'railway boxed food culture'. According to data from the Taiwan Railway Administration, more than 4,000,000 pieces of boxed food are sold per year and the number keeps growing. In conclusion, boxed food (boxed lunches) provision is a main form of food service in Taiwan and it also becomes a special tourism issue that should be investigated further. In particular, boxed food service will result in environmental impacts, the same as other food service, and these negative impacts should be identified and evaluated.

Three main types of meal boxes used in Taiwan are cardboard, PS and PP. The cardboard meal box is mainly made of paper. The PS meal box is made of polystyrene, while the PP meal box is made of polypropylene. The main purpose of industrial ecology is to evaluate and minimise impacts from economic activities. Tourism, as an economic activity, results in a full range of environmental impacts and should be regarded as any other industry. Hence, the application of industrial ecology in tourism was investigated to enhance environmental management of catering. More specifically, boxed food in Taiwan was taken as a case study by Kuo *et al.* (2005) to demonstrate this new approach.

The framework for studying boxed food was based on material flow analysis. Boxed food analysis was divided into two parts: the meal box and the contents. Meal boxes were inventoried with a life cycle assessment (LCA). According to the findings of this study, environmental impacts from a PP meal box production were more expensive than others, while those from a PS meal box production were the lowest. The life cycle inventory analysis of the contents has to be further investigated with a new approach. This new approach is an integration of the LCA with the HACCP system.

8.12.3 RTE foods

Both eating outside the home – at places like restaurants, bars, fast food outlets, workplace cafeterias and other catering services (French *et al.*, 2001; Guthrie *et al.*, 2002; Nielsen *et al.*, 2002) – and consumption of RTE foods – like take-away, home delivered and convenience foods – have increased markedly during the past decades (Ahlqvist *et al.*, 2003).

In Finland, a large share of the food that is consumed outside home is eaten at the workplace cafeteria (Lankinen, 2003), as Finns have a long tradition of eating a hot lunch during the workday. Raulio

Table 8.61 Organoleptic and physicochemical characteristics and microbiological parameters for fresh minced meat.

Raw material: Fresh minced meat **Category: Meat and their products**		
Organoleptic characteristics	• State of packaging	Veterinarian approval in documents
	• Labelling	Conformity seal coming from an animal with veterinarian seal
	• Purity state	Free of dirt and foreign matter No ice
	• Receipt temperature	7 or 12°C max
Physicochemical characteristics	• Organoleptic characteristics	Manufactured from line muscles (excluding heart muscles) If coming from fresh meat should be processed within 6 days No processing from UV or irradiation
	• Foreign matter (wood, glass, plastic)	Absence
	• Odour, colour, texture	
	• Toxic substances (insecticides, antibiotics, hormones, toxins, fertilisers, fungicides)	Absence
	• Heavy metals	Absence
Microbiological parameters	• Pathogenic micro-organisms	Absence
	• Total microbial count (cfu/g)	$<5 \times 10^5$
	• *E. coli* (cfu/g)	<50
	• *Cl. perfringens* (cfu/g)	<10
	• *St. aureus* (cfu/g)	<100
	• *Salmonella* spp.	Absence in 10 g
	• Characteristic micro-organisms	*Cl. putrefaciens*, *Enterobacter*, *E. coli* O157:H7, *Pseudomonas*, *St. aureus*, *B. cereus*, *Campylobacter jejuni*, *Cl. botulinum*, *Listeria monocytogenes*, *Salmonella* spp., *Yersinia enterocolitica*, *Cl. perfringens Parasites* (*meat*): *Toxoplasma gondii*, *Sarcocystis hominis*, *Sarcoccystis shihominis*, *Trichinella spiralis*, *Taenia*
Packaging		
Shelf life		
Storage–maintenance conditions	Refrigeration (0–4°C), freezing (<−18°C)	

et al. (2005) showed that the Finnish habit of having lunch at the workplace cafeteria has resisted major changes in working and living conditions and in social structure. However, the factors behind the overall stability of trends seem to be different for men and women. Among men, age differences in lunch-eating patterns diminished because the younger male birth cohorts ate lunches more often. Among women, the age differences increased because cafeteria use among the youngest women did not change, unlike that among the oldest group of women. According to their preliminary findings, it appears that the use of workplace cafeterias may promote healthy food habits (Raulio *et al*., 2005).

8.13 STORAGE OF FOODS UNDER COOLING

Whenever foods or their components, which are kept under cooling, have to be used, they should be removed in small quantities from the fridge so that their processing is carried out without any increase in temperature. The time the foods can remain in an inappropriate temperature depends on processing room temperature, and processing the food will undergo prior to being served.

Some of these foods are as follows:

- Raw meats, poultry and fish stored at a temperature of 5°C or lower:

Table 8.62 Organoleptic and physicochemical characteristics and microbiological parameters for frozen minced meat and beef.

Raw material: Minced meat (frozen) **Category: Meat and meat products**		
Organoleptic characteristics	• State of packaging	Free of foreign matter
	• Receipt temperature	$<-18^{\circ}C$
	• Shell	Plastic film
	• Labelling	Expiry date
Physicochemical characteristics	• Foreign matter (wood, glass, plastic)	Presence
	• Colour, texture, taste, odour	Permissible levels
	• Toxic substances (insecticides, antibiotics, hormones, toxins, fertilisers, fungicides)	Absence
	• Heavy metals	Absence
	• Mycotoxins (mainly *Aflatoxin*, *St. aureus*)	Absence
	• pH	<6.5
Microbiological parameters	• *Escherichia coli* (cfu/g)	$<10^3$
	• *Cl. perfringens* (cfu/g)	<10
	• Pathogenic micro-organisms	Absence
	• Total microbial count	$<1 \times 10^6$
	• Suggestive micro-organisms	*Cl. putrefaciens*, *Enterobacter*, *E. coli* O157:H7, *Pseudomonas*, *St. aureus*, *B. cereus*, *Campylobacter jejuni*, *Cl. botulinum*, *Listeria monocytogenes*, *Salmonella* spp., *Yersinia enterocolitica*, *Cl. perfringens Parasites* (*meat*): *Toxoplasma gondii*, *Sarcocystis hominis*, *Sarcoccystis shihominis*, *Trichinella spiralis*, *Taenia*
Packaging		
Shelf life	As indicated on the packaging	
Storage–maintenance conditions	Freezing ($<-18^{\circ}C$)	

Table 8.63 Organoleptic and physicochemical characteristics and microbiological parameters for glucose syrup.

Raw material: Glucose syrup **Category: Sweeteners**		
Organoleptic characteristics	• State of packaging	No leakages, no visible dirt, no spoilage
	• Labelling	Expiry date. If concentration in SO_2 is higher than 20 mg/kg the food destined to be used should be labelled
	• Receipt temperature	Room temperature
Physicochemical characteristics	• Foreign substance	70% w/w max
	• Equivalent to dextrose	20% w/w max
	• Ash (sulphuric acid)	1.0% w/w max
	• Colouration	Additive AZURAGE is not permitted
	• SO_2	20 mg/kg max (for confectionery products and certain foods 400 mg/kg max)
Microbiological parameters	• Characteristic micro-organisms	*Salmonella* spp., *St. aureus*, *B. cereus*
Packaging		
Shelf life	As indicated on the packaging	
Storage–maintenance conditions	Cool and dry conditions	

Table 8.64 Organoleptic and physicochemical characteristics and microbiological parameters for lemon flavour.

Raw materials: Lemon flavour **Category: Flavours**		
Organoleptic characteristics	• State of packaging • Labelling • Receipt temperature	No leakages, no visible dirt, no spoilage Lemon flavour Room temperature
Physicochemical characteristics	• Citric acid • Preservatives/antioxidants	3 g/L max
Microbiological parameters		
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions	

Table 8.65 Organoleptic and physicochemical characteristics and microbiological parameters for vegetable and tomato soups, sauces in powdered form.

Raw material: Vegetable and tomato soups, sauces in powdered form **Category: Foods of plant origin, preserved food**		
Organoleptic characteristics	• State of packaging • Labelling • Receipt temperature	No leakages, no visible dirt, no spoilage Expiry date Percentage of tomato or their products (for tomato powders). Ingredients for the rest of the powders Room temperature
Physicochemical characteristics	• Foreign matter (stones, metals etc.) • Organoleptic characteristics • Additives • Toxic substances (pesticides, insecticides) • Mycotoxins	Absence From ripe fruits, with normal macroscopic and organoleptic characters Absence Absence
Microbiological parameters	• Characteristic micro-organisms	Fungi, *Salmonella* spp.
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions	

Table 8.66 Organoleptic and physicochemical characteristics and microbiological parameters for baking powder.

Raw material: Baking powder **Category: Additives**		
Organoleptic characteristics	• State of packaging • Labelling • Receipt temperature	No leakages, no visible dirt Use by date; number of approval; food grade Room temperature
Physicochemical characteristics	• Purity • Heavy metals concentration (Pb, As, Hg)	
Microbiological parameters	• Micro-organisms	
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions	

Table 8.67 Organoleptic and physicochemical characteristics and microbiological parameters for praline.

Raw material: Praline **Category: Products with sweeteners, cocoa, chocolate**		
Organoleptic characteristics	• State of packaging • Labelling • Receipt	Closed and protected packages Production and expiry date Room temperature
Physicochemical characteristics	• Organoleptic characteristics • Heavy metals • Toxic substances (insecticides, antibiotics, pesticides) • Mycotoxins (Aflatoxin) • *Salmonella* (in 1 g)	No use of deteriorated raw materials Absence Absence Absence Absence
Microbiological parameters		Fungi, *Salmonella* spp., *St. aureus*, *B. cereus*
Packaging		
Shelf life	As indicated on the package	
Storage– maintenance conditions	Room temperature (T: 4°C) (after opening)	

Table 8.68 Organoleptic and physicochemical characteristics and microbiological parameters for sesame pulp.

Raw material: Sesame pulp **Category: Foods of plant origin**		
Organoleptic characteristics	• State of packaging • Labelling • Receipt	Closed and protected packages Production and expiry date Room temperature
Physicochemical characteristics	• Organoleptic characteristics • Solids present • Heavy metals • Toxic substances (insecticides, antibiotics, pesticides) • Mycotoxins (Aflatoxin)	Normal No Absence Absence
Microbiological parameters		Fungi, *Salmonella* spp., *St. aureus*, *B. cereus*
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions	

Table 8.69 Organoleptic and physicochemical characteristics and microbiological parameters for fried chips.

Raw material: Fried chips **Category: Products of plant origin**		
Organoleptic characteristics	• State of packaging • Organoleptic characteristics • Labelling • Receipt temperature	Sealed bags with no leakage, no visible dirt No indications of incomplete processing Production and expiry date Room temperature
Physicochemical characteristics	• Preservatives (as SO_2) • Moisture Fatty substance	<50 mg/kg 7.5% max 2%
Microbiological parameters		
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Freezing	

Table 8.70 Organoleptic and physicochemical characteristics and microbiological parameters for preserved fish roe.

Raw material: Preserved fish roe **Category: Fish and their products**		
Organoleptic characteristics	• State of packaging	No bruises, visible dirt
	• Receipt temperature	<4°C
	• Labelling	
	• State of packaging	Expiry date
Physicochemical characteristics	• Foreign matter (plastic, wood, metallic objects)	Absence
	• Odour, texture	
	• Heavy metals (Hg, Pb, Cd)	Hg <0.5 ppm
	• Mycotoxins	Absence
	• Sugar cane	<4%
	• Acidity (oleic acid)	<1%
Microbiological parameters	• Characteristic micro-organisms	*Acinetobacter*, *Proteus*, *Pseudomonas*, *Vibrio* spp., *Salmonella* spp., *Campylobacter jejuni*, *Cl. botulinum*, *Shigella* spp., *St. aureus*, *Enterobacteriaceae*, *L. monocytogenes*, *E. coli* *Parasites*: *Anisakis* spp., *Diphyllobothrium*, *Pseudoterranova*
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Refrigeration (0–4°C)	

to ensure quality
to avoid the growth of micro-organisms and increase their shelf life
to prevent the growth of pathogenic micro-organisms such as *Salmonella*.

- Whole eggs should be stored in the fridge and used until their "use by date".

Distribution of foods under cooling should be accomplished when:

foods are stored immediately after distribution
foods under cooling are stored first, frozen foods next and finally grocery products.

During serving, foods can be kept up to four hours at a temperature higher than 5°C. This is valid only once (it is not allowed to serve the same food for an hour and then again for three hours).

Frozen foods should be stored at a temperature equal to or lower than –18°C. Ice creams in display units should be stored at a temperature ≤–14°C.

Thawing of frozen foods should be carried out in the fridge at a temperature equal to or lower than 5°C. Alternatively, it could be carried out using running water at a temperature equal to or lower than 21°C for a period not greater than three hours. Food in which temperature control is required is given in Table 8.5. The high-, medium- and low-risk foods are given in Tables 8.6–8.8, respectively. In Table 8.9, the preservation times for different foods are summarised.

8.14 STORAGE OF FOODS BY HEATING

Warm foods should be stored at a temperature equal to or higher than 60°C when:

they are to be served or sold directly
they are to be transferred to the point of serving.

Table 8.71 Organoleptic and physicochemical characteristics and microbiological parameters for minced chicken.

Raw material: Minced chicken **Category: Meats and their products**		
Organoleptic characteristics	• State of packaging • Receipt temperature • Wrapping • Labelling	Free of foreign matter <−18°C Plastic film Use by date
Physicochemical characteristics	• Foreign matter (wood, glass, plastic) • Colour, texture, taste, odour • Toxic substances (insecticides, antibiotics, hormones, toxins, fertilisers, fungicides) • Heavy metals • Mycotoxins (mainly *Aflatoxin*, *St. aureus*)	Absence Acceptable Absence Absence Absence
Microbiological parameters	• *Escherichia coli* (cfu/g) • *Cl. perfringens* (cfu/g) • Pathogenic micro-organisms • Total microbial count • *St. aureus* (cfu/g) • *Salmonella* spp. • Characteristic micro-organisms	<50 <10 Absence $<1 \times 10^6$ <100 Absence in 10 g *Cl. putrefaciens*, *Enterobacter*, *E. coli* O157:H7, *Pseudomonas*, *St. aureus*, *B. cereus*, *Campylobacter jejuni*, *Cl. botulinum*, *Listeria monocytogenes*, *Salmonella* spp., *Yersinia enterocolitica*, *Cl. perfringens*
Packaging	As indicated on the label	
Shelf life		
Storage–maintenance conditions	Freezing (<−18°C)	

Table 8.72 Organoleptic and physicochemical characteristics and microbiological parameters for mustard.

Raw material: Mustard **Category: Seasoning agents and essential oils**		
Organoleptic characteristics	• State of packaging • Labelling • Receipt temperature	No leakages, no visible bruises and dirt Expiry date Room temperature
Physicochemical characteristics	• Organoleptic characteristics • Toxic substances	No use of deteriorated raw materials Absence
Microbiological parameters	• Pathogenic micro-organisms • Characteristic micro-organisms	Absence *E. coli* O157:H7, *Salmonella* spp., *Cl. botulinum*, *Cl. perfringens*, *B. cereus*
Packaging		
Shelf life	As indicated on the label	
Storage–maintenance conditions	Refrigeration (0–4°C)	

Table 8.73 Organoleptic and physicochemical characteristics and microbiological parameters for canned products.

Raw materials: Canned products **Category: Foods of plant origin**		
Organoleptic characteristics	• State of packaging	No leakages, no visible dirt, no spoilage (rust on the package)
	• Labelling	Type and preservative. Expiry date
	• Receipt temperature	Room temperature
	• Foreign matter (plastic, wood, metal, soil, stones)	Absence
Physicochemical characteristics	• Brine	Used only once
	• Taste, odour, colour, texture	Acceptable
	• Pesticide residues (parathion, malathion, arsenic and lead preparations)	No residues should be detected
	• Mycotoxins (mainly in fruits)	Absence
	• Colouring agents (inorganic/organic)	Absence
Microbiological parameters	• Characteristic micro-organisms	*Vegetables*: Fungi, *Pseudomonas*, *Cl. botulinum*, *Listeria monocytogenes*, *B. cereus*, *Salmonella* spp., *Shigella* spp., *St. aureus* (toxin), Hepatitis A, Norwalk viruses *Fruits*: Hepatitis A, Norwalk virus, *E. coli* O157:H7
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions	

Those foods could be stored for three hours at a temperature lower than 60°C; however, the person in charge should prove that the dwell time at this temperature did not go beyond three hours.

More specifically, meat (beef and other meat products) with its exterior surface baked, but its geometrical centre raw, and with a temperature at the centre lower than 75°C, when served should be stored at a temperature at the centre greater than 60°C.

Products which have been processed thermally during their preparation must be cooled immediately after this processing. Foods should be cooled down from 60 to 10°C over a period of three hours maximum and then stored in the fridge at a temperature of 5°C or lower. To facilitate cooling, foods should be separated into pieces or cooled per batch. Equipment used for cooling should not be overloaded with products beyond the anticipated weight for which it has been manufactured.

8.15 GENERAL PRACTICES

- All foods should remain covered at all times except during serving. Plastic caps, films and containers are used.
- Adequate amounts of cookware.
- Storage of intermediate and final products should be in different fridges to raw materials and raw products.
- Soups and sauces stored using heating in a thermochamber should be stirred periodically (every 15 minutes) to ensure there are no cold points.
- Fridges and refrigerators should be placed away from heat sources (e.g. kitchens) in a well ventilated place.
- Different fridges should be used for storage of cooked and raw foods and should be labelled accordingly. Minibars are excluded.
- If storage is not feasible in different fridges, cooked foods should be placed over raw foods.
- Different freezers should be used for freezing of fresh and frozen foods.
- All foods should be covered.
- If tins get opened, their content should be transferred to appropriate covered containers before placement in the fridge.
- Warm foods should not be placed in the fridge.
- Older stocks should be used first. FIFO (first in first out) should be applied.

Table 8.74 Organoleptic and physicochemical characteristics and microbiological parameters for milk powder.

Raw material: Milk powder **Category: Milk, eggs and their products**		
Organoleptic characteristics	• State of packaging	No bruises, no expansion, no leakages and no visible dirt
	• State of purity of material	Absence of foreign matter
	• Labelling	Expiry date and origin
	• Receipt temperature	Room temperature
Physicochemical characteristics	• Taste, odour, colour	
	• Toxic substances (insecticides, antibiotics, pesticides)	Absence
	• Heavy metals	Absence
	• Colouring agents	Absence
	• Acidity	6–8° (Soxhlet–Henckel)
	• Sorbic compounds (E200, E202, E203)	<1000 mg/Kg
Microbiological parameters	• *Salmonella* spp. (in 1 g)	Absence
	• Pathogens	Negative
	• Total microbial count	Negative
	• Coliforms	Negative
Packaging		
Shelf life	As indicated on the package	
Storage–maintenance conditions	Cool and dry conditions Following opening of the package it should be stored in the fridge (0–4°C)	

- Freezers with an automatic defrost system or without an automatic defrost system should be cleaned every month.
- Food inside the fridges should be checked daily for their quality and their expiry date. Frozen food should be checked once a week.
- Data loggers should exist in fridges and freezing chambers and daily records should be kept.
- In case of mechanical damage to a refrigerator, the following action should be taken:

  Report of the damage to the maintenance engineer
  Temperature control:

  - if temperature is between 5 and 10°C, foods are transferred to another fridge
  - if temperature is over 10°C, foods must be rejected.
  - In case of mechanical damage of a freezer:

  Report of the damage to the maintenance engineer
  Temperature control:

  - if temperature is up to –12°C, foods are transferred to another freezer
  - if temperature is over –12°C, then frozen foods must be rejected.

The organoleptic and physicochemical characteristics and microbiological parameters for different types of edible products are given in Tables 8.10–8.74.

8.16 FUTURE DIRECTIONS

The notion of 'playing safe' often leads to the acceptance of over-conservative regimes such as the chilling time of 90 minutes for cooked beef as recommended by the New South Wales Health Department (1998a,b). In practice, cooked beef cooled to 7.5°C within 15 minutes did not support the outgrowth of *C. perfringens* (Juneja, 1999). Furthermore, the need for six decimal reduction of *C. botulinum* during cooking (New South Wales Health Department, 1998b) can also be questioned – the high populations of this pathogen are extremely rare. In order to 'strengthen' the food safety design, the application of natural antimicrobials (spices, salt, sugar, organic acids, bacteriocins and lactate) in a synergistic combination of subtle

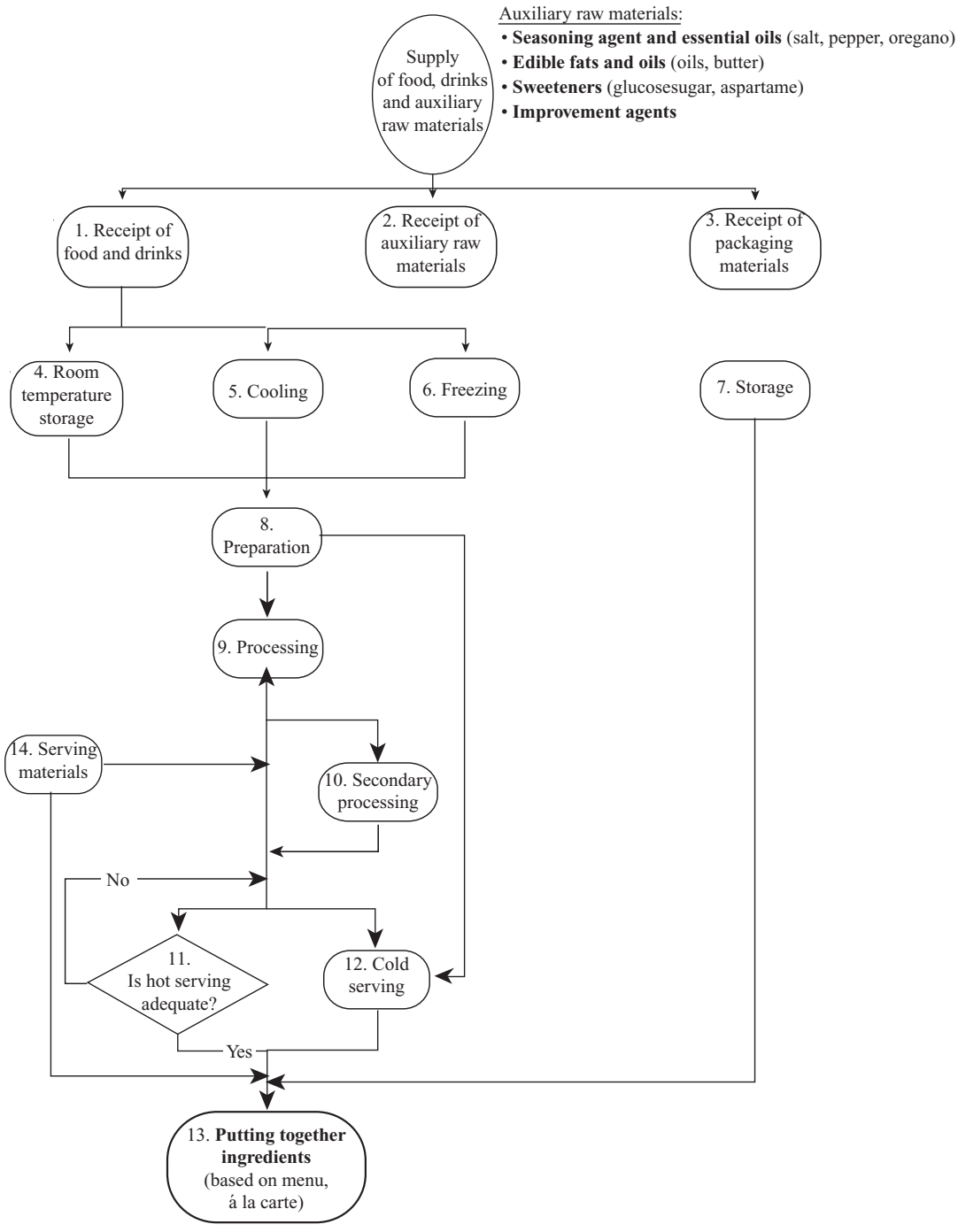

Fig. 8.7 Flow diagram of food processing in hotels (food preparation, places supporting kitchen, restaurants, bar, room service).

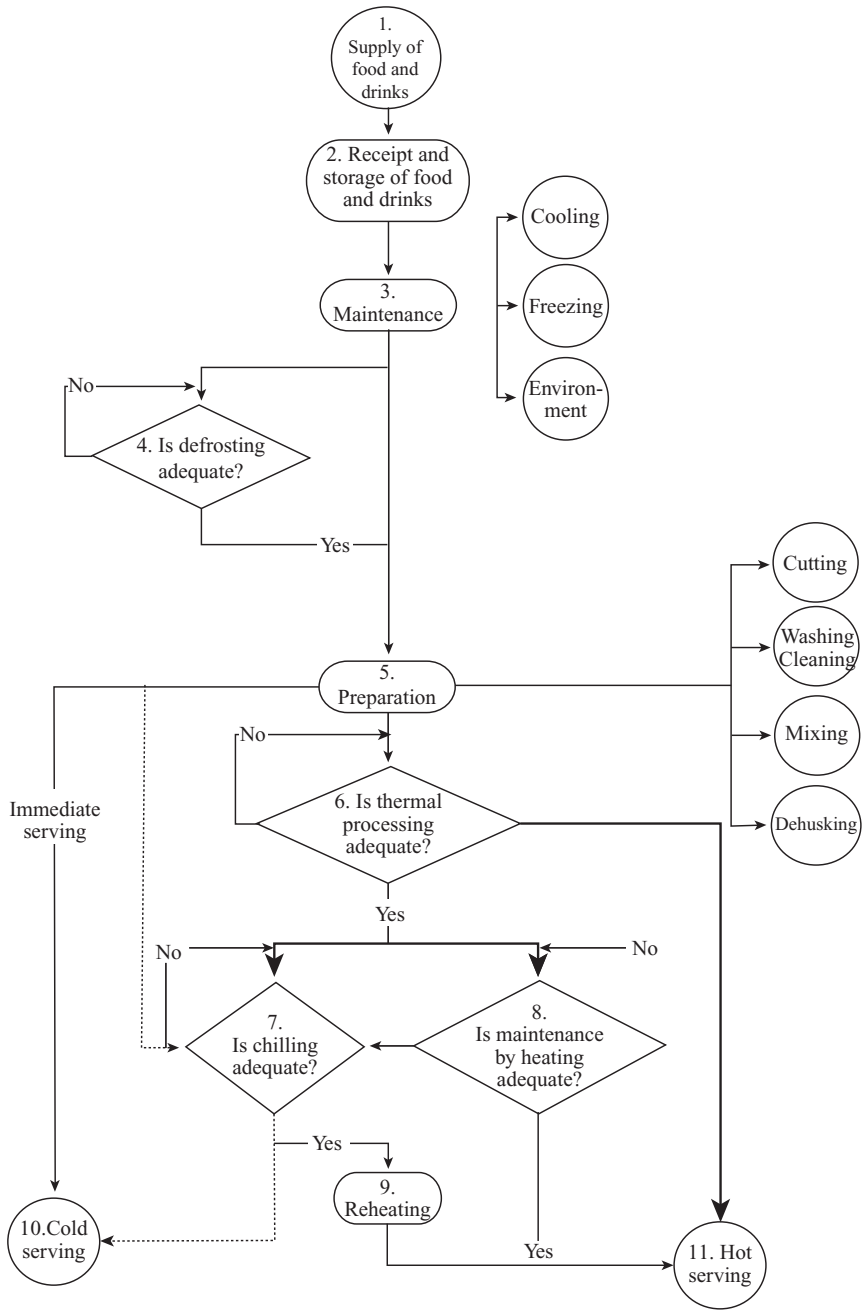

Fig. 8.8 Flow diagram of supply of food and drinks.

Table 8.75 Effective hygiene risk management.

Hygienic efficiency	Cross-contamination
Process effectiveness	Hands free systems (potential transfer)
Hands	
Washing (antimicrobial vs. bland soap)	Wet vs. dry hands (transfer rate)
Nail brush	
Rinsing	Regularly cleaned and sanitised
Drying	Surfaces
Alcoholic hand sanitisers	Raw food/cooked food isolation
Hand surrogates	
Gloves	
Utensils	
Deli/bakery papers	

Adapted from Michaels *et al.* (2004), with permission of Blackwell Publishing .

preservation hurdles can be investigated. The effectiveness of protective cultures in traditional cook–chill foods against such pathogens as *Salmonella* and *Listeria* can be tested.

Further improvements in validity and accuracy of predictive models would reduce the need for challenge studies. In commercial practices, operators often innovate by modifying traditional and LSL cook–chill methods. Some upmarket food services use prime cuts of meat/fish, which are only sealed/browned on the day prior to consumption, the core temperature never reaches the requirements of the codes of practices (Rodgers, 2005). In some cases, a product is 'hygienically' packaged without the pasteurisation step. Companies supplying recyclable packaging are experimenting with LSL meals plated at a CPU. All these new processes should be validated.

Overall, it has been difficult to reach a consensus among stakeholders on precisely which intervention measures should be employed in food-handling environments to effectively reduce infectious intestinal disease (IID) rates. Through a study of over 300 reports of outbreaks attributed to ill or asymptomatic food handlers, hazards and contributory factors responsible for foodborne illness outbreaks were identified by Michaels *et al*. (2004). With the use of the risk analysis software platforms, e.g. Analytica, Risk and GoldSim, models were created to explore measures of hygiene effectiveness.

Analytica is well suited for model development and visual overview of how the various factors involved in foodborne transmission relate to each other, whereas the event tree format used with Risk allows easy and clear evaluation of data outputs. GoldSim being primarily a programme used for environmental modelling contains the reservoir function necessary to adequately model the types cross-contamination and die-off events that occur in food processing and service facilities. The flow diagrams of food processing in hotels and supply of food and drinks are given in Figs. 8.7 and 8.8, respectively.

Through the use of appropriate models, results of various personal hygiene intervention measures were explored for the development of preventive management strategies, designed to improve food-handling practices at various levels of the food chain. These included exclusion of ill food handlers, vaccination for hepatitis A virus, hand washing combined with drying, wearing of gloves, and use of instant hand sanitisers and fingernail brushes. This was accomplished by modelling pathogen transfer and transmission routes from food handler via foods, beverages and common contact surfaces using GoldSim and Monte Carlo simulations. A lottery model was also created to understand risk as an interrelated overlapping extreme-driven system, consisting of the three components of hygiene frequency, efficacy and cross-contamination. Data gaps were identified with respect to areas where considerable variability and uncertainty exists in order to establish research priorities. Effective hygiene risk management is based on the interaction between hygienic efficiency and cross-contamination (Table 8.75).

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9
Conclusions and Future Directions

Ioannis S. Arvanitoyannis

Many countries are still in the process of developing National Food Safety Programmes, while developed policies of others do not fully reflect the true nature and extent of current emerging food safety problems. Some of the major constraints in the development of effective food safety policies include:

- Lack of appreciation of the nature and extent of national food safety problems
- Lack of awareness of the consequences of contaminated food on the nation's health status and economic development, and the need for investigation and research
- Lack of sound, cost-effective methods of identifying specific food safety problems
- Lack of organised consumer demand for food safety
- The fragmented nature and/or overlap of responsibilities for food safety, food control and food trade, in different government departments and at various levels, often lead to conflicts of interest
- Insufficient allocation of resources, including personnel, to respond appropriately to the problem
- Lack of periodic evaluation and updating of food safety policies to meet contemporary problems
(FAO, 2002).

In view of current trends in global food legislation and the requirements for international trade, national governments should be encouraged to strengthen their legislation by developing a framework food safety law that will:

- Clearly identify and limit the particular authorities, functions and activities of government agencies
- Define the methods to enforce legislation and identify penalties for breaches of the law
- Clearly identify the responsibilities of the food sector and all individuals and enterprises involved in the food chain
- Contain provisions to ensure food safety and consumer protection in matters other than those relating to health, such as fraud and deception
- Provide a mechanism for the introduction of subsidiary legislation and specific regulations, such as codes of practice, that will contain specific details on such matters as enforcement procedures, regulations on hygiene, use of food additives and labelling, licensing of food premises and import/export regulations
- Be compatible with actual European Community legislation and adherent to Codex Guidelines and Standards (Marovatsanga, 2000).

Appropriate education programmes are needed that are aimed at domestic food preparation and storage, particularly in countries where access to the cold food chain is not always possible. Improved household food preparation and storage methods and increased awareness of health risks, all contribute to improved health status. Education programmes should be targeted at:

- Organisation of national seminars to raise awareness of the importance of food safety in order to prevent diarrhoeal diseases and associated malnutrition and to develop a plan of action, including education and extension programmes, for collaboration of health workers with food safety authorities
- Training of trainers who are involved in the education of health workers and primary school teachers in food safety
- Utilisation of mass media for dissemination of information on health issues and food safety
- Incorporation of principles of food safety in school curricula
(http://www.food.gov.uk/multimedia/pdfs/principles23mar07).

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Table 9.1 Important factors when assessing a food safety programme of companies.

Criteria	Definition	Application
Effectiveness	The degree of attainment of predetermined objectives	Increase in numbers of food premises inspected
Impact	The overall effect on health and related socio-economic development	• What is the overall effect on health and related socio-economic development? • Has there been a decrease in foodborne disease or related economic costs?
Efficiency	The relationship between the results obtained and the resources expended	What is the relationship between the results obtained and resources spent?
Progress	The comparison of actual with scheduled activities to ensure that operations are proceeding as planned and as scheduled	• Has the programme proceeded as planned? • Have the milestones been achieved?
Adequacy	Determining whether sufficient attention has been paid to certain previously determined courses of action	Has the programme adequately covered all the target audiences; has sufficient attention been paid to the vulnerable groups, e.g. infants, elderly?
Relevance	The rationale for adopting policies and strategies in terms of their response to health needs as well as social and economic activities	• Are the initial policies still relevant? • Is there a need for change? • Are activities performed relevant to the specific problems faced by the country?

Adapted from FAO/WHO (2004); http://www.euro.who.int/document/FOS/gsr.fsp6.pdf; http://www.food.gov.uk/multimedia/pdfs/principles23mar07.

Factors that are important when assessing a programme for food safety in food businesses are summarised in Table 9.1.

The monitoring of selected milestones and schedules provides officials with a continuous progress evaluation. Some examples of strategy indicators include:

- Number of professional staff (by category) to be trained within 1 year, 2 years etc.
- Number of programmes for food safety to be created in a specific period, such as:
  monitoring of veterinary residues
  monitoring of pesticides
  monitoring of heavy metals
  monitoring of mycotoxins
  monitoring of antimicrobial contamination
  monitoring of antibiotic resistance
- Cost of implementing the strategy in year 1, year 2 etc. (http://www.euro.who.int/document/FOS/gsr.fsp6.pdf).

Longitudinally integrated safety assurance (LISA) extends the management of food safety beyond food processing to include the distribution stage and all steps until consumption. Epidemiological studies are required to identify the critical control points and to design HACCP procedures for livestock producers. The 'seven P' approach for implementing LISA is given below:

- P1. Premises (ensuring the construction and the equipment comply with GMDPs, with special emphasis on ease of cleaning and disinfection and screening against vermin)
- P2. Procurement (providing raw materials and ingredients of the best microbiological quality; if necessary, reaching an agreement with suppliers that unavoidably contaminated raw materials be decontaminated by procedures not adversely affecting the wholesomeness, quality or acceptability of products so treated)
- P3. Processing (sterilisation, cooking, drying, cooling, MAP and introducing, where required, microbiocidal treatments as a third, essential line of defence against potentially dangerous contamination, relying on lethality levels derived from risk analysis)
- P4. Preservation (freezing, chilling, MAP, vacuum, packaging for preventing loss of initial microbial integrity during post-process storage, transportation, distribution or culinary preparation, due to either contamination or colonisation)
- P5. Personnel (educating and particularly motivating line staff to follow prescribed procedures, with special emphasis on providing those responsible for safety assurance with simple tools that allow them, themselves, to assess the effectiveness of recommended practices)

- P6. Post-manufacture surveillance [(a) validating adherence to GMDPs by monitoring fresh product samples and specimens approaching the storage limit and (b) promptly identifying and rectifying incidental failures]
- P7. Public concern about certain processing procedures (taking seriously consumers' anxiety about perceived adverse health impacts of certain modes of processing food for safety; communicating the views of impartial academic expert panels on such matters)
(Mossel *et al.*, 1995).

Prerequisite requirements control generic hazards and form part of GHP/GMP. The following list gives examples of the types of prerequisite requirements covering three key areas: product, premises and personnel. Not all of these are relevant to all types of food business, but they provide a checklist of the types of controls that operators should consider depending on the size and complexity of their business. Some examples of prerequisite requirements are given below:

1. Product
   - Monitoring supplier competence
   - Supplier auditing
   - Raw material specifications (including packing)
   - Product specifications
   - Production specifications
   - Production and process control (including temperature control)
   - Allergen control
   - Foreign body control
   - Product or ingredients sampling and testing, as appropriate, using recognised test methods and competent laboratories
   - Batch identification and 'one up one down' traceability
   - Quarantine procedures
   - Monitoring and acting upon costumer complaints
   - Product incident management plan, including corrective actions
   - Product withdrawal and recall procedures
   (http://www.fdf.org.uk/responses/fdf_response_incident_prevention.pdf).
2. Premises
   - Good hygiene design
   - Cleaning schedules
   - Maintenance schedules
   - Chemical control programme
   - Pest control programme
   - Water supply and quality
   - Waste management procedures
   (FSA, 2007).
3. Personnel
   - Documented procedures for personal hygiene
   - Appropriate medical screening of food handlers
   - Appropriate training of personnel
   (http://www.fdf.org.uk/responses/fdf_response_incident_prevention.pdf).

A prerequisite programme must be in place before a HACCP system is developed. This will enable the HACCP system to focus on the significant product and process food safety hazards that require specific control to assure food safety. Prerequisite programmes should be documented and records maintained (FSA, 2007). Food businesses may wish to keep up to date with legislative changes/best practice and to be aware of potential new food safety issues though, for example:

- Monitoring Rapid Alert System for Food and Feed (RASFF) notifications and Food Standards Agency food alerts
- Reviewing scientific literature
- Contact with and advice from research associations and trade associations.

An industry incident management plan should include detailed procedures and supporting documentation covering, as appropriate, the following:

- Objective
- Incident investigative procedures
- Incident management procedures
- List of incident management team members and deputies
- Specified responsibilities and tasks of the members of the incident management team
- Operational procedures for the incident management team
- Operational procedures for specific tasks
- Product withdrawal/recall procedures
- Incident status register
- Checklists for tasks
- Internal company contact list
- Customer contact list
- Supplier contact list
- Enforcement agency contact list (including police)
- Service providers/consultants contact list
- Key document samples or templates
- Training procedure
- Testing procedure
- Plan review procedure
(http://www.fdf.org.uk/responses/fdf_response_incident_prevention.pdf).

Microbiological risk assessment (MRA) is resource intensive in terms of scientific input and time, and effective incorporation of MRA in the development

of food safety standards, guidelines and related texts requires systematic and transparent application of a framework for managing foodborne hazards (FAO/WHO, 1997; WHO, 2000).

Establishment of MRA policy requires an adequate definition of the scope and purpose of the MRA, and consists of documented guidelines for judgements or policy choices. Establishing MRA policy helps ensure that the MRA is systematic, complete and transparent. It also protects the scientific integrity of the MRA process. It is the responsibility of risk managers, but should be decided upon in cooperation with risk assessors and other interested parties, preferably before the MRA commences (FAO/WHO, 2002).

MRA is a particularly useful tool when the risk management issue is complex. A risk characterisation should provide insights about the nature of the risk, even when this is not captured by a qualitative or quantitative estimate of risk. The risk assessor may also be able to use the risk model to run a number of simulations to compare the likely effectiveness of alternative methods of risk reduction enabling the risk manager to consider and compare risk management options.

Performance criteria, alone or in combination, may be implemented as food safety measures in GHP-based and/or HACCP-based food control systems. In the context of HACCP, a food safety measure is 'any action and activity that can be used to prevent or eliminate a food safety hazard or reduce it to an acceptable level' and a critical control point (CCP) is 'a step at which control can be applied and is essential to prevent or eliminate a food safety hazard or reduce it to an acceptable level' (FAO/WHO, 2001). A performance criterion can be set at any step in the food chain, and specifies at least the same level of hazard control as the 'acceptable level' to be achieved at a CCP.

Many parameters such as raw material, processing, distribution, storage, preparation and food use scenarios have to be taken into account in the implementation of food control systems that incorporate performance criteria. Different scenarios can provide different food control options, and improvements in food safety, i.e. leading to different food safety objectives (FSOs), can be simulated using MRA. These simulations can also be useful in the establishment of CCPs and critical limits in generic HACCP plans.

Where a ubiquitous pathogen occurs in a number of foods, a preliminary risk management goal may be to determine which foods should be targeted for more stringent food safety measures to achieve the greatest reduction in overall foodborne risks, e.g. *Listeria monocytogenes* in ready-to-eat foods. Relative risk reductions for particular hazard/food combinations can be predicted from MRA.

An MRA could be used to predict changing risks from the same hazard-food commodity, and facilitate design of monitoring programmes so as to effectively validate such predictions, e.g. differences due to season, region or country. Furthermore MRA may be used to explain apparent changes in reported incidences of foodborne disease that may have been brought about by different laboratory methods, intensified reporting systems or increased awareness of a particular foodborne disease.

An MRA may serve as a check on representativeness of data on human health risks gained from monitoring. Where predictions on risk from the MRA do not match monitoring or surveillance data, further scientific investigations will be required, e.g. investigation of the sensitivity and specificity of the monitoring programme (FAO/WHO, 2002).

The use of heat for the inactivation of microorganisms is the most common process in food preservation today. The future of thermal death determination of bacteria will probably rely on predictive thermal inactivation kinetics modelling. Complex multifactorial experiments and analyses to quantify the effects and interactions of additional intrinsic and extrinsic factors and development of 'enhanced' predictive models are warranted to ensure the microbiological safety of thermally processed foods. It should be useful to determine the possible effects of injury to vegetative cells and spores that may result from mild heat treatments and the factors in foods that influence the recovery of cells and spores heated at these low temperatures (Novak *et al*., 2001).

Nowadays, application of new technologies (high pressure, high voltage pulsed electric fields) where no or less heat is applied is very attractive for the maintenance of quality (Bushnell *et al*., 1993; Calik *et al*., 2002; Mertens and Knorr, 1992). However, the following facts limit their applicability: (a) bacterial spores remain tolerant to most of the new techniques (apart from irradiation) so that, sterilisation on a commercial basis, as opposed to pasteurisation, is currently possible in several countries, (b) food components influence greatly the efficacy of pressure and electroporation and (c) the kinetics of inactivation are different from those resulting from heating.

Furthermore, the desired 'equivalence' with well-established safe technology is required. The main pathogens targeted by heat pasteurisation of milk are *Mycobacterium* and *Brucella* species, and *Coxiella burnetii*; for liquid egg, salmonellae; for sous vide and similarly processed foods, the spores of non-proteolytic strains of *Clostridium botulinum*. The

new pasteurisation processes should deliver at least equivalent safety factors against these organisms. In addition, however, it must be accepted that other vegetative pathogens may show a higher degree of resistance to the alternative methods of processing than do the organisms mentioned above; for example, *L. monocytogenes* and verotoxin-producing strains of *Escherichia coli* may need particular consideration. It would be necessary to determine the relevant pathogen that showed the highest resistance to the proposed type of treatment, and to specify the reduction in viable numbers that should be achieved (Gould, 2005).

In view of the lack of systematic kinetic data and the interpretation of non-linear death kinetics for non-thermal treatments, the food manufacturers are recommended to follow the guidelines given by the International Commission on Microbiological Specifications for Foods (ICMSF, 2001a,b) and to maintain a good safety 'track record' for new technologies will be very important.

The industry should pay particular attention in terms of cleaning to the following factors:

- The faulty design and incorrect positioning of food processing equipment
- Recontamination of equipment that has been previously cleaned
- Inadequate time for cleaning or cleaning too infrequently
- Insufficient or poor-quality labour employed
- Misuse of cleaning and disinfecting agents by gross variation from the recommended concentrations
- Wrong mental attitudes of management and operatives to an important operation
  (Forsythe and Hayes, 1998).

Cleaning and disinfection are important unit operations that are carried out in each food factory on a regular basis. Prior to disinfecting, cleaning of the surface is necessary to remove organic compounds adhere to the surface. In practice, 90–95% of the micro-organisms present are removed by an efficient cleaning protocol (Krop, 1990). A wide range of disinfectants are available, which can be divided into the following groups based on their mode of action (Table 9.2):

- halogen-releasing agents (HRAs)
- quaternary ammonium compounds (QACs)
- peroxygens
- alcohols
- aldehydes
- (bis)phenols
- biguanides
  (van Asselt and te Giffel, 2005).

Predicting pathogen resistance against current disinfectants would be very useful for application in food factories and hospitals. Whether micro-organisms will survive disinfection in practice depends on more than one factor (Baquero *et al*., 1998). Although not every detail is known, it is possible to determine whether a disinfectant will be effective based on the following information:

- Type of bacteria – metabolic state
- Revival of injured cells/biodiversity of micro-organisms
- Influence of remaining organic matter/biofilms
- Processing conditions (temperature, pH).

Disinfectants for use on food contact surfaces should ideally have the following properties:

- Capable of rapidly killing micro-organisms and, in particular, equally effective against both Gram-positive and Gram-negative bacteria. The majority of mould spores should be killed and the destruction of bacterial spores would be an added advantage
- Reasonably stable in the presence of organic residues and, if necessary, effective in the presence of hard water salts
- Non-corrosive and non-staining to plant surfaces of whatever type
- Odourless or have an inoffensive odour
- Readily soluble in water and readily rinsable
- Stable during prolonged storage in concentrated form and stable during short-term storage in dilute form.
- Competitively priced and cost effective in use
  (Forsythe and Hayes, 1998).

The guideline for cleaning and disinfection is that disinfection can be effective only when the equipment or surface is properly cleaned prior to the disinfection (Krop, 1990). Any remaining organic matter will inactivate the disinfectant and micro-organisms will not be affected (Kraemer, 1998). A second reason is that organic compounds act as a protective layer for the micro-organisms. This is also the case when micro-organisms have formed a biofilm where, as a result of nutrient limitation, a reduced growth rate makes the specific micro-organisms less susceptible to disinfectants (Brown and Gilbert, 1993; Luppens, 2002). The fact that micro-organisms can form biofilms, implicating a change in their growth characteristics, can also result in resistance against disinfectants for the following reasons:

Table 9.2 Disinfectants and their modes of action.

Biocide	Mode of action	Representative agents	Advantages	Disadvantages	Application	Reference
Halogen-releasing agents (HRAs)	Halogenation/ oxidation	Chlorine-based compounds (sodium hypochlorite, chlorine dioxide, sodium dichloroisocyanurate (NaDCC), iodine	• Chlorine dioxide (ClO_2) is effective against bacteria, viruses and spores • ClO_2 produces no harmful by-products as trihalomethanes, nor does it react with ammonia	• Staining human skin and plastic parts of equipment • Iodine has a relatively higher price than chlorine	Alfalfa seeds	Hoxey and Thomas (1999); Krop (1990)
Quaternary ammonium compounds (QACs)	Electrostatic (ionic) interaction	Tri-alkylbenzyl-ammonium compounds and tetra-alkyl-ammonium compounds	• QACs have residual action • They remain active on surfaces for approximately 1 day	• They are more expensive • Removing the disinfectant from the surface by flushing with water becomes difficult • There are possible residues in the product	Fish	Kraemer (1998); Tatterson and Windsor (2001)
Peroxygens	Oxidation	Hydrogen peroxide and peracetic acid	• Sterilise packaging material prior to filling • They are bactericidal and sporicidal • They are active against Gram-positive bacteria	• They are not so active against Gram-negative bacteria • Peroxygens corrode on tools and equipment and are aggressive to human tissues	Fruits and vegetables	McDonnell and Russell (1999); McDonnell *et al.* (2002); Reuter (1998)
Alcohols (ethanol)	Protein denaturation	Ethyl alcohol (ethanol), isopropyl alcohol (isopropanol) and *n*-propanol	• They are used for the decontamination of hard surfaces of equipment • They are quick reacting • They have a broad spectrum of antimicrobial activity • They inhibit growth of vegetative bacteria, viruses and fungi	• They are more expensive than QACs and chlorine • They are not applied on large, industrial scale	Industrial equipment, temperature probes, working surfaces, scales	Setlow *et al.* (2002)

(*Continues*)

Table 9.2 (Continued)

Biocide	Mode of action	Representative agents	Advantages	Disadvantages	Application	Reference
Aldehydes	Alkylation reaction	Glutaraldehyde and formaldehyde	• They are active in a wide range of bacteria, viruses, moulds and spores • They are easily removed from surfaces • They are (bio)degradable	• Their activity is very easily influenced by remaining (protein) fouling • It is thought that formaldehyde can have mutagenic effects	Surfaces	McDonnell and Russell (1999)
(Bis)phenols	Penetration/ partition phospholipids bilayer	Triclosan and hexachlorophene	• They are active against bacteria, fungi and algae	• They are highly toxic to humans	Food packaging material, medicated soaps, hand cleaning gels, toothpaste	Hugo and Russell (1999); Vermeiren *et al.* (2002)
Biguanides	Electrostatic (ionic) interaction	Chlorhexidine, alexidine and polymeric biguanides	• They have antibacterial activity	• Efficacy of chlorhexidine is greatly reduced by the presence of organic matter	Food industry, swimming pools, mouth wash, mouth spray	Hugo and Russell (1999); McDonnell and Russell (1999)

- Exclusion/influence of the disinfectant by the formation of a slimy layer surrounding the cell
- Chemical reaction of the layer with disinfecting agents
- Limited availability of key nutrients results in decreased growth rate
- The attachment to surfaces causes depression of genes associated with sessile existence which coincidentally affects antimicrobial susceptibility (Brown and Gilbert, 1993).

Detergents must be capable of removing many different types of soil under a variety of conditions; the list of properties required for a good detergent is therefore an extensive one. Detergents in food industries should be:

1. Readily soluble in water at the desired temperature
2. Non-corrosive to equipment surfaces
3. Non-irritating to the skin and eyes
4. Non-toxic
5. Odourless
6. Biodegradable
7. Economical in use
8. Readily rinsable
9. Wet the surface of soil, that has a lower surface tension than water
10. Disperse insoluble materials that might otherwise form aggregates
11. Dissolve soluble soils, both organic and inorganic
12. Emulsify fat and oils
13. Saponify fats, that is convert fats into soluble soaps
14. Sequester calcium and magnesium salts dissolved in hard waters so that their precipitation is prevented and cleaning efficiency is not impaired.

Detergents may be conveniently classified as:

- Inorganic alkalis – caustic and non-caustic
- Inorganic and organic acids
- Surface active agents – anionic, non-ionic, cationic and amphoteric
- Sequestering agents – inorganic and organic (Forsythe and Hayes, 1998).

The efficiency of process line sanitation can be checked by visual inspection or by using microbiological techniques. An experienced inspector is expected to know where to look for signs of inadequate cleaning but residual soils do vary in their visual detectability and high-intensity lighting must be directed onto surfaces during inspection. In spite of these shortcomings, visual inspections are worthwhile provided they are performed assiduously. The most commonly used tests for the cleanliness of surfaces are by ATP-bioluminescence and microbiological culture (Gould, 2005).

As a concluding remark, it should be stressed that the implementation of ISO 22000 ultimately lies in the food industry and depends greatly on the application of Prerequisite Programmes (PPs). The greater the number and effectiveness of applied PPs, the lower the number of resulting CCPs. Therefore, it is not strange to come across ISO 22000 studies where there is not a single CCP!

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