

# MEAT PROCESSING TECHNOLOGY

## FOR SMALL- TO MEDIUM- SCALE PRODUCERS



**Gunter Heinz**  
**Peter Hautzinger**



**RAP PUBLICATION 2007/20**

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Peter Hautzinger**

**FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS  
REGIONAL OFFICE FOR ASIA AND THE PACIFIC  
Bangkok, 2007**

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## TABLE OF CONTENTS

Chapter		Page no.
1	Foreword, Acknowledgement, Authors .....	ii - iv
2	Introduction .....	v
3	Meat, fat and other edible carcass parts .....	1
4	Principles of meat processing echnology .....	17
5	Selection and grading of raw materials for meat processing .....	43
6	Non-meat ingredients.....	59
7	Seasonings used in meat processing .....	83
8	Heat treatment of meat products .....	87
9	Categories of processed meat products .....	97
10	Fresh processed meat products .....	103
11	Raw-fermented sausages.....	115
12	Raw-cooked meat products .....	127
13	Precooked-cooked meat products .....	149
14	Cured meat cuts .....	171
15	Processed products made of chicken meat .....	187
16	Meat products with high levels of extenders and fillers .....	195
17	Traditional / ethnic meat products .....	213
18	Meat drying.....	221
19	Simple meat processing under basic conditions .....	243
20	Casings .....	249
21	Packaging of fresh and processed meat .....	265
22	Canning / sterilization of meat products.....	277
23	Handling and maintenance of tools and core equipment.....	297
24	Simple test methods for meat products .....	315
25	Meat processing hygiene.....	339
26	Cleaning and sanitation in meat plants .....	369
27	Annex I recipes for processed meat products .....	381
28	Annex II glossary .....	429
29	Index .....	447

## FOREWORD

Meat is the most valuable livestock product and for many people serves as their first-choice source of animal protein. Meat is either consumed as a component of kitchen-style food preparations or as processed meat products. Processed meat products, although in some regions still in their infancy, are globally gaining ground in popularity and consumption volume.

Meat processing has always been part of FAO's livestock programmes, not only because of the possibility of fabricating nutrient-rich products for human food, but also owing to the fact that meat processing can be a tool for fully utilizing edible carcass parts and for supplying shelf-stable meat products to areas where no cold chain exists. Moreover, small-scale meat processing can also be a source of income for rural populations.

In the mid eighties to early nineties of the last century, FAO published two books on meat processing (Animal Production and Health Series No. 52 and 91) in order to familiarize food processors in developing countries with meat processing technologies. However, due to the time elapsed since then they no longer fully reflect current techniques and processing procedures used in the meat sector.

FAO initiated two major projects in this sector. In the mid nineties and in early 2000, in cooperation with the Common Fund for Commodities (CFC) and the German Development Agency GTZ/CIM, FAO ran two comprehensive regional training and development projects on meat processing technology, the first one in sub-Saharan Africa and the second one in Asia.

The experience gained in these two meat processing projects led to the decision that an updated manual on meat processing technology should be prepared, which should take into account the above mentioned publications. It should also represent not only the latest developments of meat processing technology but also use modern publication techniques such as digital photography and computer-created charts and graphs in order to visually clarify and explain facts and procedures described in the text.

The result is a comprehensive compendium on all important topics relevant to the small- to medium-size meat processing sector, with more than 400 colour photographs, drawings and graphs. It can be anticipated that this publication will be a useful guidebook not only for meat processing industries in developing countries, but for all those who plan to establish small business enterprises in this sector or are interested, from the training point of view, in this important part of food manufacture.

A handwritten signature in blue ink, appearing to read 'He Changchui', with a long, sweeping horizontal stroke extending to the right.

He Changchui  
Assistant Director-General and  
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## ACKNOWLEDGEMENT

This manual is based on training materials used in FAO-organized Regional Training in Meat Processing Technology for Asian countries. The Animal Products Development Center (APDC) in Manila, Philippines offered its premises for the training courses and was instrumental in the preparation of the manuscript through the provision of staff and equipment for experimental and development work, photographs and technical drawings and in the finalizing of the text, for which we are grateful. The review of the text by APDC scientists is also highly appreciated.

The production of the manual is a joint activity between the Animal Products Group of the Animal Production Service (AGAP) of FAO Headquarters in Rome, Italy and the Livestock Section of the FAO Regional Office for Asia and the Pacific (RAP) in Bangkok, Thailand. The hard work of Anthony Bennett, Animal Production Officer (AGAP), in reviewing the publication and the technical editing is highly appreciated. AGAP's contribution to the printing cost is acknowledged.

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## INTRODUCTION

Meat consumption in developing countries has been continuously increasing from a modest average annual per capita consumption of 10 kg in the 1960s to 26 kg in 2000 and will reach 37 kg around the year 2030 according to FAO projections. This forecast suggests that in a few decades, developing countries' consumption of meat will move towards that of developed countries where meat consumption remains stagnant at a high level.

The rising demand for meat in developing countries is mainly a consequence of the fast progression of urbanization and the tendency among city dwellers to spend more on food than the lower income earning rural population. Given this fact, it is interesting that urban diets are, on average, still lower in calories than diets in rural areas. This can be explained by the eating habits urban consumers adopt. If it is affordable to them, urban dwellers will spend more on the higher cost but lower calorie protein foods of animal origin, such as meat, milk, eggs and fish rather than on staple foods of plant origin. In general, however, as soon as consumers' incomes allow, there is a general trend towards incorporating more animal protein, in particular meat, in the daily diet. Man's propensity for meat consumption has biological roots. In ancient times meat was clearly preferred, consequently time and physical efforts were invested to obtain it, basically through hunting. This attitude contributed decisively to physical and mental development of humankind. Despite the growing preference in some circles for meatless diets, the majority of us will continue eating meat. It is generally accepted that balanced diets of meat and plant food are most effective for human nutrition.

Quantitatively and qualitatively, meat and other animal foods are better sources of protein than plant foods (except soy bean products). In meat, the essential amino acids – the organic acids that are integral components of proteins and which cannot be synthesized in the human organism – are made available in well balanced proportions and concentrations. As well, plant food has no Vitamin B<sub>12</sub>; thus animal food is indispensable for children to establish B<sub>12</sub> deposits. Animal food, in particular meat, is rich in iron, which is of utmost importance to prevent anemia, especially in children and pregnant women.

In terms of global meat production, over the next decade there will be an increase from the current annual production of 267 million tons in 2006 to nearly 320 million tons by 2016. Almost exclusively, developing countries will account for the increase in production of over 50 million tons. This enormous target will be equivalent to the levels of overall meat production in the developing world in the mid-1980s and place an

immense challenge on the livestock production systems in developing countries.

The greater demand for meat output will be met by a further shift away from pastoral systems to intensive livestock production systems. As these systems cannot be expanded indefinitely due to limited feed availability and for environmental reasons, other measures must be taken to meet growing meat demand. The only possible alternatives are making better use of the meat resources available and reducing waste of edible livestock parts to a minimum.

This is where meat processing plays a prominent role. It fully utilizes meat resources, including nearly all edible livestock parts for human food consumption. Meat processing, also known as further processing of meat, is the manufacture of meat products from muscle meat, animal fat and certain non-meat additives. Additives are used to enhance product flavour and appearance. They can also be used to increase product volume. For specific meat preparations, animal by-products such as internal organs, skin or blood, are also well suited for meat processing. Meat processing can create different types of product composition that maximizes the use of edible livestock parts and are tasty, attractive and nourishing.

The advantage of meat processing is the integration of certain animal tissues (muscle trimmings, bone scraps, skin parts or certain internal organs which are usually not sold in fresh meat marketing) into the food chain as valuable protein-rich ingredients. Animal blood, for instance, is unfortunately often wasted in developing countries largely due to the absence of hygienic collection and processing methods and also because of socio-cultural restrictions that do not allow consumption of products made of blood. While half of the blood volume of a slaughtered animal remains in the carcass tissues and is eaten with the meat and internal organs, the other half recovered from bleeding represents 5-8 percent of the protein yield of a slaughter animal. In the future, we cannot afford to waste such large amounts of animal protein. Meat processing offers a suitable way to integrate whole blood or separated blood fractions (known as blood plasma) into human diets.

Thus, there are economic, dietary and sensory aspects that make meat processing one of the most valuable mechanisms for adequately supplying animal protein to human populations, as the following explains:

- All edible livestock parts that are suitable for processing into meat products are optimally used. In addition to muscle trimmings, connective tissue, organs and blood, this includes casings of animal origin that are used as sausage containers.

- Lean meat is one of the most valuable but also most costly foods and may not regularly be affordable to certain population segments. The blending of meat with cheaper plant products through manufacturing can create low-cost products that allow more consumers access to animal protein products. In particular, the most needy, children and young women from low-income groups, can benefit from products with reduced but still valuable animal protein content that supply essential amino acids and also provide vitamins and minerals, in particular iron.
- Unlike fresh meat, many processed meat products can be made shelf-stable, which means that they can be kept without refrigeration either as (1) canned heat sterilized products, or (2) fermented and slightly dried products or (3) products where the low level of product moisture and other preserving effects inhibit bacterial growth. Such shelf-stable meat products can conveniently be stored and transported without refrigeration and can serve as the animal protein supply in areas that have no cold chain provision.
- Meat processing “adds value” to products. Value-added meat products display specific flavour, taste, colour or texture components, which are different from fresh meat. Such treatments do not make products necessarily cheaper; on the contrary in many cases they become even more expensive than lean meat. But they offer diversity to the meat food sector, providing the combined effect of nutritious food and food with excellent taste.

## Processing technology

Meat processing technologies were developed particularly in Europe and Asia. The European technologies obviously were more successful, as they were disseminated and adopted to a considerable extent in other regions of the world – by way of their main creations of burger patties, frankfurter-type sausages and cooked ham. The traditional Asian products, many of them of the fermented type, are still popular in their countries of origin. But Western-style products have gained the upper hand and achieved a higher market share than those traditional products.

In Asia and Africa, there are a number of countries where meat is very popular but the majority of consumers reject processed meat products. This is not because they dislike them but because of socio-cultural reasons that prohibit the consumption of certain livestock species, either pork or beef depending on the region. Because processed products are mostly composed of finely comminuted meat, which makes identifying the animal species rather difficult, or are frequently produced from mixes of meat from different animals, consumers stay away from those products to avoiding eating the wrong thing. But when the demand for meat increases and a regular and cost-effective supply can only be

achieved by fully using all edible livestock parts, consumers will need to adjust to processed meat products, at least to those where the animal source can be identified. Younger people already like to eat fast-food products such as beef burgers or beef frankfurters. Outlet chains for such products and other processed meat products will follow when the demand increases.

## **This manual**

In regions where processed meat products are widely popular and therefore produced in great variety, the consumer may get confused with the multitude of different products and product names. With this manual, we have set out to clarify the types of meat products and the techniques for producing them, with a specific focus on operational and technical requirements for small- and medium-scale processing units. As a first approach in international meat literature, this manual classifies existing meat products according to their processing technology into six clearly differentiated groups. Practically every processed meat product can be integrated into one of these groups. This system provides transparency in the meat-products market and allows for the exact characterization and defining of differences in the processing technology. The processing technologies, including meat processing equipment to be used, are described in detail in the respective chapters. In addition, Annex I contains detailed recipes for representative products for each group.

In meat-product manufacturing, the basic processing technologies, such as cutting and mixing, are accompanied by various additional treatments and procedures, depending on the type and quality of the final product. Such treatments involve curing, seasoning, smoking, filling into casings or rigid containers, vacuum packaging, cooking or canning/sterilization. Due to the importance of these procedures, suitable and up-to-date techniques for carrying out these processes and the equipment needed are described in separate chapters but are also referred to in the manual in connection with the respective product groups.

Processing technologies for meat products will not deliver satisfactory results if there is no adequate meat hygiene in place. In the interest of food safety and consumer protection, increasingly stringent hygiene measures are required at national and international trade levels. Key issues in this respect are Good Hygienic Practices (GHP) and Hazard Analysis and Critical Control Point Schemes (HACCP), which are discussed in detail in the manual. Extensive knowledge on hazards that microorganisms cause is indispensable in modern meat processing. Thus, along with technological aspects of meat processing, the manual includes reference to related aspects of meat processing hygiene, including causes for meat product spoilage and food borne illnesses as well as

cleaning and sanitation in meat processing. For the purpose of consumer protection and the quality control of meat products, simple test methods are provided that can be carried out at the small enterprise level without sophisticated laboratory set-ups. However, some of these procedures have to be understood as screening methods only and cannot supplement specific laboratory control, which may be officially required.

As the authors, we have endeavoured to incorporate in this publication a series of practical topics, which are important in meat processing but which are usually not sufficiently referred to or not found at all in meat processing handbooks. This includes the handling and maintenance of equipment and tools, workers' appliances, workers' safety in using equipment and tools, meat processing under basic conditions, traditional meat drying, preparation of natural sausage casings from intestines of slaughter animals, the comprehensive listing and description of non-meat ingredients, the manufacturing of meat products with high levels of extenders and fillers, as well as sources and processing technologies for animal fats in meat product manufacturing. This much-needed practical advice and information will also provide incentives towards product diversification to meat processors.

This manual was designed in the first place as a guideline for practical meat processing activities, with focus on the small- and medium-scale sector. The technical content, therefore, was written to make it clearly and easily understood by processing artisans. However, in a number of cases it was necessary to provide more scientific background information for the explanation of technical measures recommended. The description of these mostly physical/chemical aspects is attached to the respective topics but clearly marked in grey or blue boxes. Readers who do not require the additional information will have no problems in understanding the content of the chapters without reading the text in those boxes. Readers who want an overall view of the topic will find the necessary details in the boxes.

This manual is intended for meat processors in developing countries, in particular those who want to improve the existing manufacturing methods and anyone who is interested in entering this specific food sector. Because the content reflects the most current techniques and procedures globally applied in the small- and medium-size meat processing enterprises and includes numerous instructive photographs and drawings, its use is also encouraged for information and teaching purposes.

Gunter Heinz  
Peter Hautzinger



# MEAT, FAT AND OTHER EDIBLE CARCASS PARTS

## (Types, structure, biochemistry)

### Sources of meat, fat and animal by-products.

Meat, fat and other carcass parts used as raw materials for the manufacture of processed meat products are mainly derived from the domesticated animal species **cattle**, **pigs** and **poultry** and to a lesser extent from **buffaloes**, **sheep** and **goats**. In some regions other animal species such as **camels**, **yaks**, **horses** and **game animals** are used as meat animals but play only a minor role in meat processing.

In this context, **meat** can be defined as “the muscle tissue of slaughter animals”. The other important tissue used for further processing is **fat**. Other edible parts of the slaughtered animal and often used in further processing are the **internal organs**<sup>1</sup> (tongue, heart, liver, kidneys, lungs, diaphragm, oesophagus, intestines) and other slaughter by-products (blood, soft tissues from feet, head).

A special group of internal organs are the **intestines**. Apart from being used as food in many regions in particular in the developing world, they can be processed in a specific way to make them suitable as sausage casings (see chapter on Casings, page 249). Some of them are eaten with the sausage; others are only used as container for the sausage mix and peeled off before consumption.

The **skin** of some animal species is also used for processed meat products. This is the case with pork skin and poultry skin, in some cases also with calf skin (from calf heads and legs).

For more details on the utilization of animal tissues for processed meat products see also chapter “Selection and grading of meat materials for processing” (page 43).

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1) With the emergence of BSE (Bovine Spongiform Encephalopathy), some edible animal tissues from ruminants, in particular brain, have been declared “specified risk materials (SRM)” and have to be condemned in BSE affected areas.

## Muscle meat

### Chemical composition of meat

In general, meat is composed of **water**, **fat**, **protein**, **minerals** and a small proportion of **carbohydrate**. The most valuable component from the nutritional and processing point of view is protein.

Protein contents and values define the quality of the raw meat material and its suitability for further processing. Protein content is also the criterion for the quality and value of the finished processed meat products. Table 1 shows the chemical composition of fresh raw and processed meats.

**Table 1: Content of water, protein, fat, ash (in percent) and calories**  
(approximate values for selected raw and processed food products)

	Product	Water	Protein	Fat	Ash	Calories / 100g
FRESH	Beef (lean)	75.0	22.3	1.8	1.2	116
	Beef carcass	54.7	16.5	28.0	0.8	323
	Pork (lean)	75.1	22.8	1.2	1.0	112
	Pork carcass	41.1	11.2	47.0	0.6	472
	Veal (lean)	76.4	21.3	0.8	1.2	98
	Chicken	75.0	22.8	0.9	1.2	105
	Venison (deer)	75.7	21.4	1.3	1.2	103
	Beef fat (subcutaneous)	4.0	1.5	94.0	0.1	854
	Pork fat (back fat)	7.7	2.9	88.7	0.7	812
PROCESSED	Beef, lean, fried	58.4	30.4	9.2		213
	Pork, lean, fried	59.0	27.0	13.0		233
	Lamb, lean, fried	60.9	28.5	9.5		207
	Veal, lean, fried	61.7	31.4	5.6		186
	Raw-cooked sausage with coarse lean particles (ham sausage)	68.5	16.4	11.1		170
	Raw-cooked sausage finely comminuted, no extender	57.4	13.3	22.8	3.7	277
	Raw-cooked sausage (frankfurter type)	63.0	14.0	19.8	0.3	240
	Precooked-cooked sausage (liver sausage)	45.8	12.1	38.1		395
	Liver pate	53.9	16.2	25.6	1.8	307
	Gelatinous meat mix (lean)	72.9	18.0	3.7		110
Raw-fermented sausage (Salami)	33.9	24.8	37.5		444	
	Milk (pasteurized)	87.6	3.2	3.5		63
	Egg (boiled)	74.6	12.1	11.2		158
	Bread (rye)	38.5	6.4	1.0		239
	Potatoes (cooked)	78.0	1.9	0.1		72

As can be seen from the table, **water** is a variable of these components, and is closely and inversely related to the fat content. The fat content is higher in entire carcasses than in lean carcass cuts. The fat content is also high in processed meat products where high amounts of fatty tissue are used.

The value of animal foods is essentially associated with their content of **proteins**. Protein is made up of about 20 aminoacids. Approximately 65% of the proteins in the animal body are skeleton muscle protein, about 30% connective tissue proteins (collagen, elastin) and the remaining 5% blood proteins and keratin (hairs, nails).

### Histological structure of muscle tissue

The muscles are surrounded by a connective tissue membrane, whose ends meet and merge into a tendon attached to the skeleton (Fig. 1(b)). Each muscle includes several **muscle fibre bundles** which are visible to the naked eye (Fig. 1(c)), which contain a varying number (30-80) of **muscle fibres** or muscle cells (Fig. 1(d) and Fig. 2) up to a few centimetres long with a diameter of 0.01 to 0.1 mm. The size and diameter of muscle fibres depends on age, type and breed of animals. Between the muscle fibre bundles are blood vessels (Fig. 1(e)) as well as connective tissue and fat deposits (Fig. 1(f)). Each muscle fibre (muscle cell) is surrounded by a cell membrane (sarcolemma) (Fig. 2, blue). Inside the cell are **sarcoplasm** (Fig. 2, white) and a large number of filaments, also called **myofibrils** (Fig. 1(g) and Fig. 2, red).

The *sarcoplasm* is a soft protein structure and contains amongst others the red muscle pigment **myoglobin**. *Myoglobin* absorbs oxygen carried by the small blood vessels and serves as an oxygen reserve for contraction of the living muscle. In meat the *myoglobin* provides the red meat colour and plays a decisive role in the curing reaction (see page 34).

The *sarcoplasm* constitutes about 30 percent of the muscle cell. The *sarcoplasmatic proteins* are **water soluble**. About 70 percent of the muscle cell consists of thousands of *myofibrils*, which are solid protein chains and have a diameter of 0.001 – 0.002 mm. These proteins, which account for the major and nutritionally most valuable part of the muscle cell proteins, are **soluble in saline solution**. This fact is of utmost importance for the manufacture of certain meat products, in particular the *raw-cooked products* (see page 97, 127) and *cured-cooked products* (see page 97, 171). A characteristic of those products is the heat coagulation of previously liquefied myofibril proteins. The achieved structure of the coagulated proteins provides the typical solid-elastic texture in the final products.

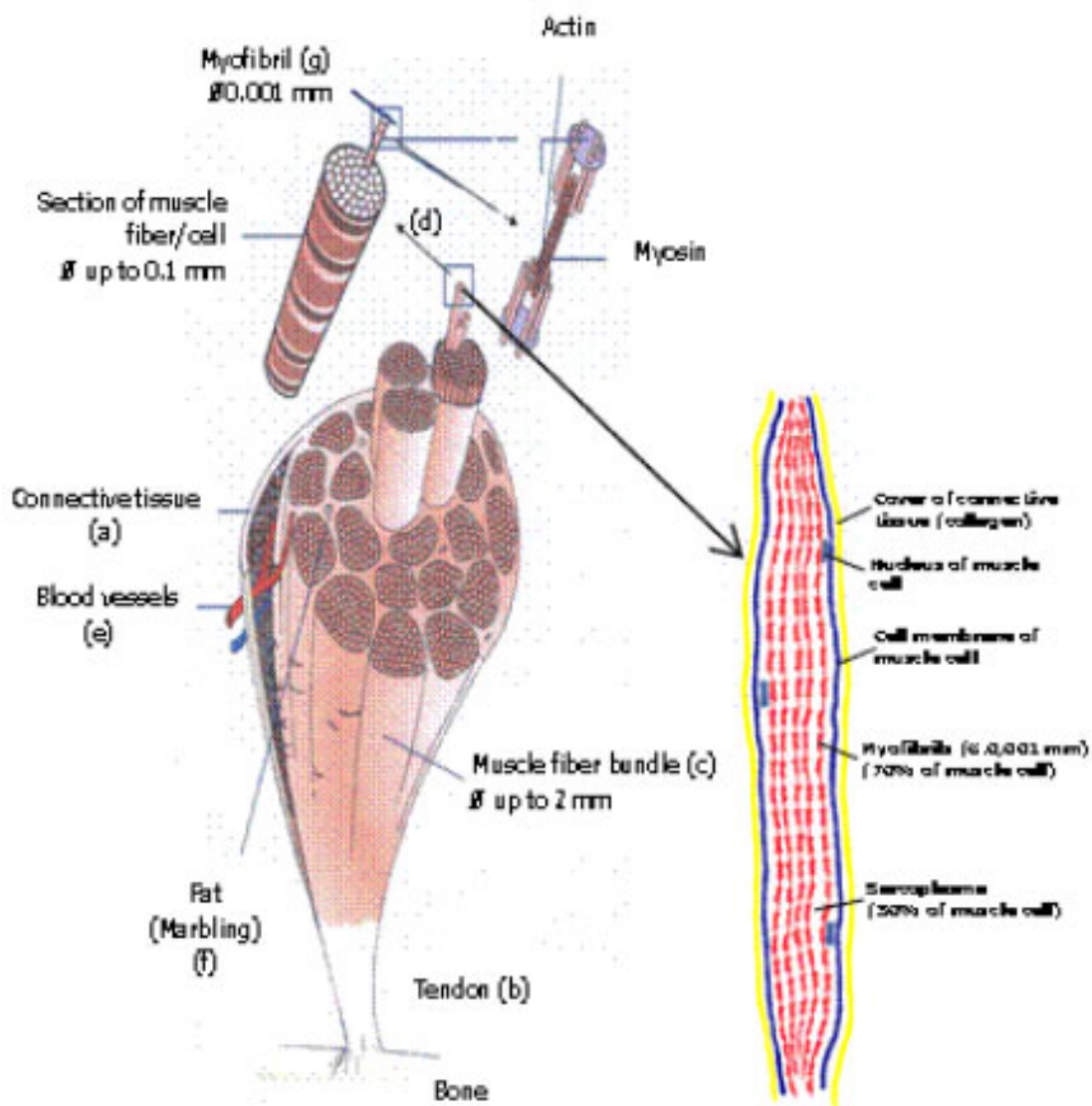


Fig. 1: Muscle structure (skeletal muscle)

Fig. 2: Entire muscle fibre or muscle cell, 0.01-0.1 mm

## Changes of pH

Immediately post-mortem the muscle contains a small amount of muscle specific carbohydrate, called **glycogen**<sup>1</sup> (about 1%), most of which is broken down to lactic acid in the muscle meat in the first hours (up to 12 hours) after slaughtering. This biochemical process serves an important function in establishing acidity (low pH) in the meat.

<sup>1)</sup> In the live animal glycogen is the energy reserve for the muscles used as fuel for muscle contraction.

The so-called glycolytic cycle starts immediately after slaughter in the muscle tissue, in which glycogen, the main energy supplier to the muscle, is broken down to **lactic acid**. The build up of lactic acid in the muscle produces an increase in its acidity, as measured by the **pH**. The pH of normal muscle at slaughter is about 7.0 but this will decrease in meat. In a normal animal, the ultimate pH (expressed as  $pH_{24}$  = 24 hours after slaughter) falls to around **pH 5.8-5.4**. The degree of reduction of muscle pH after slaughter has a significant effect on the quality of the resulting meat (Fig. 3).

The typical **taste** and **flavour** of meat is only achieved after sufficient drop in pH down to 5.8 to 5.4. From the *processing* point of view, meat with pH 5.6-6.0 is better for products where good water binding is required (e.g. frankfurters, cooked ham), as meat with higher pH has a higher water binding capacity. In products which lose water during fabrication and ripening (e.g. raw ham, dry fermented sausages), meat with a lower pH (5.6–5.2) is preferred as it has a lower water binding capacity (see also page 322).

The pH is also important for the **storage life** of meat. The lower the pH, the less favourable conditions for the growth of harmful bacteria. Meat of animals, which had depleted their glycogen reserves before slaughtering (after stressful transport/handling in holding pens) will not have a sufficient fall in pH and will be highly prone to bacterial deterioration (see also box page 5/6).

#### **PSE and DFD** (see Fig. 3)

In stress susceptible animals pH may fall very quickly to pH 5.8 – 5.6 while the carcass is still warm. This condition is found most often in pork. It can be recognized in the meat as a pale colour, a soft, almost mushy texture and a very wet surface (**pale, soft, exudative = PSE meat**). PSE meat has lower binding properties and loses weight (water) rapidly during cooking resulting in a decrease in processing yields.

A reverse phenomenon may arise in animals which have not been fed for a period before slaughter, or which have been excessively fatigued during transportation and lairage. In these cases, most of the muscle glycogen has been used up at point of slaughter and pronounced acidity in the meat cannot occur. The muscle  $pH_{24}$  does not fall below pH 6.0. This produces **dark, firm, dry (DFD) meat**. The high pH cause the muscle proteins to retain most of their bound water, the muscle remain swollen and they absorb most of the light striking the meat surface, giving a dark appearance.

Dark meat has a “sticky” texture. Less moisture loss occurs during curing and cooking as a result of the higher pH and the greater water-holding capacity but salt penetration is restricted. Conditions for growth of microorganisms are therefore improved resulting in a much shorter “shelf life”. DFD conditions occur both in beef and pork.

DFD meat should not be confused with that resulting from mature animals through the presence of naturally dark pigmentation. PSE and DFD conditions can to a certain extent be prevented or retarded through humane treatment and minimization of stress to animals prior to slaughter.

PSE and DFD meat is **not unfit** for human consumption, but not well suited for cooking and frying (PSE loses excessive moisture and remains dry due to low water binding capacity while DFD meat remains tough and tasteless due to the lack of acidity).

Nevertheless, for meat processing purposes, PSE and DFD meat can still be utilized, preferably **blended** with normal meat. PSE meat can be added to meat products, where water losses are desirable, such as dry-fermented sausages, while DFD meat can be used for raw-cooked products (frankfurter type) where high water binding is required.

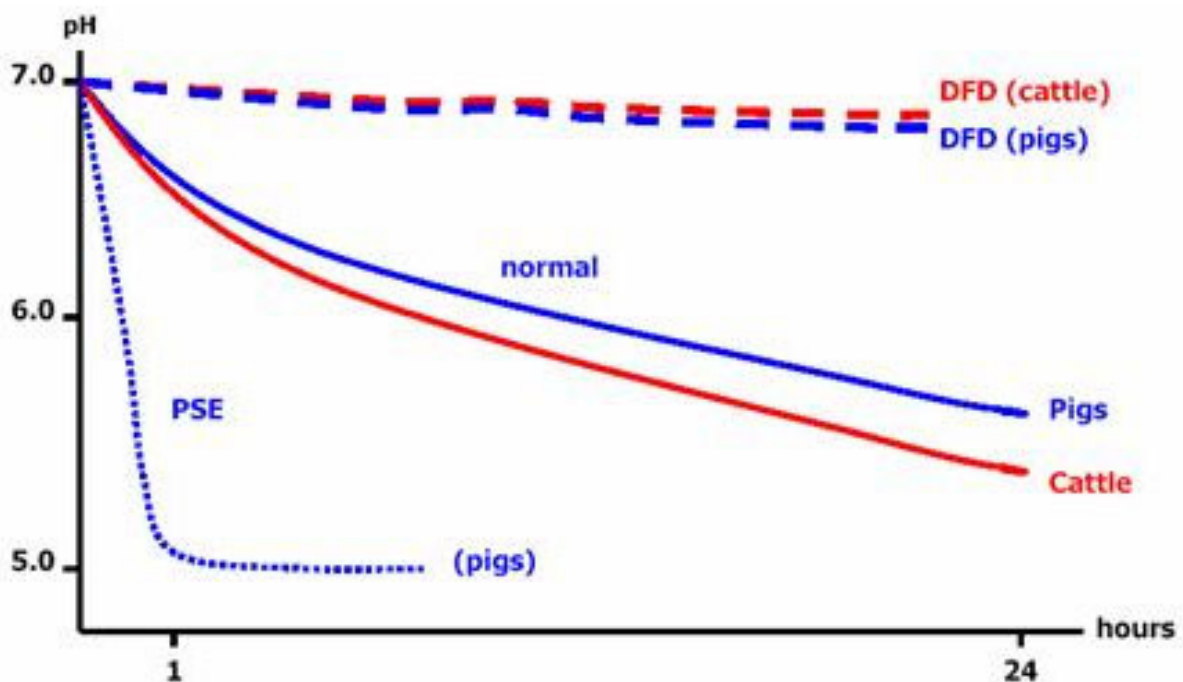


Fig. 3: Changes of pH

## Meat colouring

The red pigment that provides the characteristic colour of meat is called **myoglobin**. Similar to the blood pigment haemoglobin it transports oxygen in the tissues of the live animal. Specifically, the myoglobin is the oxygen reserve for the muscle cells or muscle fibres. Oxygen is needed for the biochemical process that causes muscle contraction in the live animal. The greater the myoglobin concentration, the more intense the colour of the muscle. This difference in myoglobin concentration is the reason why there is often one muscle group lighter or darker than another in the same carcass.



Fig. 4: Fresh meat cut (beef) with intense red meat colour

Myoglobin concentration in muscles also differs among animal species. Beef has considerably more myoglobin than pork, veal or lamb, thus giving beef a more intense colour (Fig. 4). The maturity of the animal also influences pigment intensity, with older animals having darker pigmentation. The different myoglobin levels determine the curing capability of meat. As the red curing colour of meat results from a chemical reaction of myoglobin with the curing substance nitrite, the curing colour will be more intense where more muscle myoglobin is available (see "Curing", page 34).

## Water holding capacity

**The water holding capacity (WHC)** of meat is one of the most important factors of meat quality both from the consumer and processor point of view. Muscle proteins are capable of holding many water molecules to their surface. As the muscle tissue develops acidity (decrease of pH) the water holding capacity decreases (Fig. 5, 429, 430).

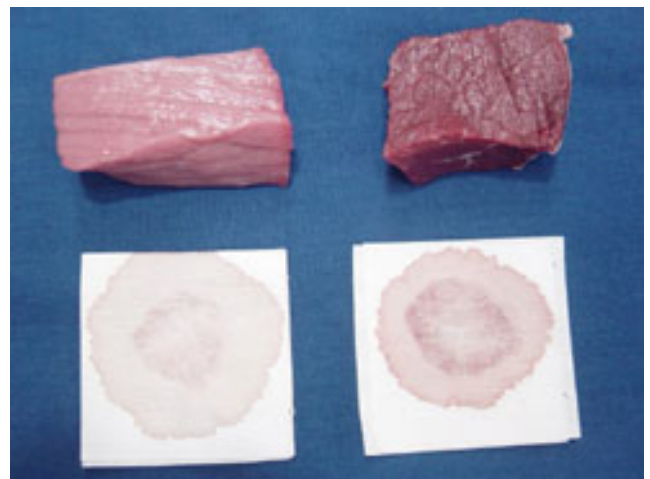


Fig. 5: Compression test<sup>1</sup>, different water holding capacity of muscles. Left: Sample with low WHC. Right: Dark meat sample with good WHC (less water pressed out)

<sup>1</sup>) Compression instrument see page 325

Water bound to the muscle protein affects the eating and processing quality of the meat. To obtain good yields during further processing including cooking, the water holding capacity needs to be at a high level (except for uncooked fermented and/or dried products which need to lose water during processing, see page 115, 171).

Water holding capacity varies greatly among the muscles of the body and among animal species. It was found that beef has the greatest capacity to retain water, followed by pork, with poultry having the least.

### Tenderness and flavour

Meat tenderness plays an important role, where entire pieces of meat are cooked, fried or barbecued. In these cases some types of meat, in particular beef, have to undergo a certain ripening or ageing period before cooking and consumption in order to achieve the necessary tenderness (Fig.6). In the fabrication of many processed meat products the toughness or tenderness of the meat used is of minor importance. Many meat products are composed of comminuted meat, a process where even previously tough meat is made palatable. Further processing of larger pieces of meat (e.g. raw or cooked hams) also results in good chewing quality as these products are cured and fermented or cured and cooked, which makes them tender.

The taste of meat is different for different animal species. However, it may sometimes be difficult to distinguish the species in certain food preparations. For instance, in some dishes pork and veal may taste similar and have the same chewing properties. Mutton and sometimes lamb has a characteristic taste and smell, which originates from the fat. Even small quantities of **fat**, e.g. inter- and intramuscular fat, may imprint this typical smell and taste on the meat, particularly of meat from old animals. **Feed** may also influence the taste of meat (e.g. fish meal). In addition, the **sex** of the animal may also give a special taste and smell to the meat. The most striking example is the pronounced urine-like smell when cooking old boar's meat. Meat fit for human consumption but with slightly



Fig. 6: Aging/ripening of beef hind quarter in cooling room

untypical smell and flavour, which may not be suitable for meat dishes, can still be used for certain processed meat products. However, it should preferably be blended with “normal” meat to minimize the off-odour. Also intensive seasoning helps in this respect.

**Fig. 7: Meat from different livestock species**

Typical retail cuts



**Beef top round slice**



**Pork rib chops from loin**



**Lamb ribs**



**Chicken leg**

The typical desirable taste and odor of meat is to a great extent the result of the formation of **lactic acid** (resulting from glycogen breakdown in the muscle tissue) and organic compounds like aminoacids and di- and tripeptides broken down from the meat proteins.

In particular the aged (“matured”) meat obtains its characteristic taste from the breakdown to such substances. The “meaty” taste can be further enhanced by adding **monosodium glutamate (MSG)** (0.05-0.1%), which can reinforce the meat taste of certain products (see page 73). MSG is a frequently used ingredient in some meat dishes and processed meat products in particular in Asian countries.

## Animal fats

Fatty tissues are a natural occurring part of the meat carcass. In the live organism, fatty tissues function as

- Energy deposits (store energy)
- Insulation against body temperature losses
- Protective padding in the skin and around organs, especially kidney and heart.

Fatty tissue (Fig. 8) is composed of cells, which like other tissue cells, have cell membranes, nucleus and cell matrix, the latter significantly reduced to provide space for **storing fat**. Fats, in the form of triglycerides, accumulate in the fat cells. Well fed animals accumulate large amounts of fat in the tissues. In periods of starvation or exhaustion, fat is gradually reduced from the fat cells.

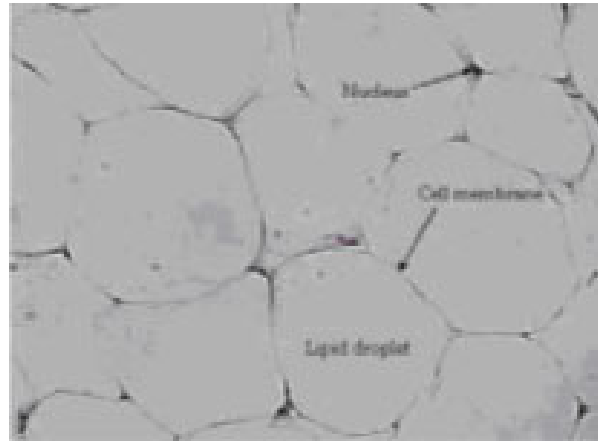


Fig. 8: Fatty tissue (fat cells filled with lipids)

In the animal body there are **subcutaneous fat deposits** (under the skin) (Fig. 10(a/b)) and Fig. 14(a)), fat **deposits surrounding organs** (e.g. kidney, heart) (Fig. 10(d) and Fig. 16(a)) or fat deposits between muscles (**intermuscular fat**, (Fig. 9(a)). Fat deposits between the muscle fibre bundles of a muscle are called **intramuscular fat** (Fig. 9(b)) and lead in higher accumulations to *marbling*. Marbling of muscle meat contributes to tenderness and flavour of meat. Many consumers prefer marbling of meat for steaks and other roasted meat dishes.

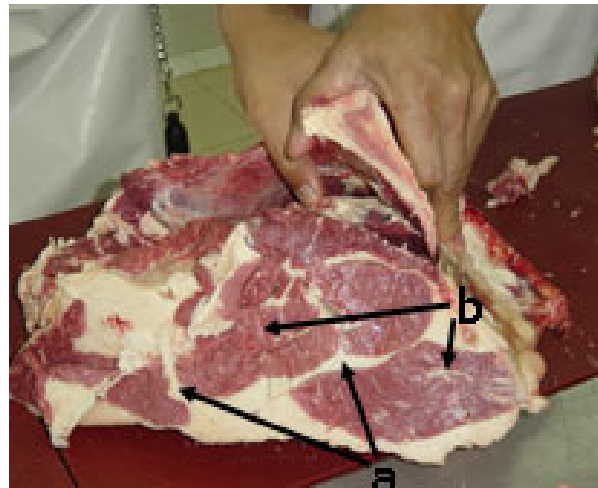


Fig. 9: Intermuscular fat (a) (around individual muscles) and intramuscular fat (b) (inside muscle tissue)

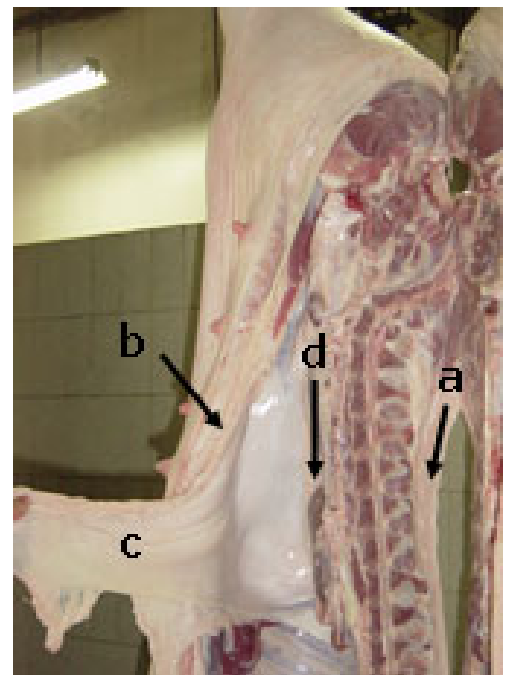
For *processed meat* products, fats are added to make products **softer** and also for **taste** and **flavour improvement**. In order to make best use of animal fats, basic knowledge on their selection and proper utilization is essential.

Fatty tissues from certain animal species are better suited for meat product manufacture, fats from other species less or not suited at all. This is mainly for sensory reasons as taste and flavour of fat varies between animal species. Strong differences are also pronounced in older animals, with the well known example of fat from old sheep, which most consumers refuse. However, this aspect is to some extent subjective as consumers prefer the type of animal fat they are used to.

Availability also plays a role when fatty tissues are used for processing. Some animal species have higher quantities of fatty tissue (e.g. pigs), others lesser quantities (e.g. bovines) (Table 1). Pig fat is favoured in many regions for processing purposes. It is often readily available but has a suitable tissue structure, composition and unpronounced taste which make it readily usable. Fresh pork fat is almost odour- and flavourless. Body fats from other animal species have good processing potential for the manufacture of meat products, but the addition of larger quantities is limited by availability and some undesirable taste properties.

### Pork fat

The **subcutaneous fats** from pigs are the best suited and also most widely used in meat processing, e.g. **backfat** (Fig. 10(a), Fig. 12), **jowl fat** (Fig. 11(b), Fig. 12) and **belly** (Fig. 10(b) and Fig. 12). These fatty tissues are easily separated from other tissues and used as separate ingredients for meat products. Also the **intermuscular fats** occurring in certain locations in muscle tissues are used. They are either trimmed off or left connected (e.g. intermuscular fat in muscle tissue) and processed together with the muscle meat. Subcutaneous and intermuscular fats are also known as "body fats". Another category are the **depot-fats**, located in the animal body around internal organs. These fats can also be manually separated. In rare cases mesenterical (**intestinal**) fats of pigs are used for soft meat products (e.g. liver sausage), but only in small quantities as they cause untypical mouthfeel in final products. The **kidney fat** (Fig. 10(d)) and **leafe fat** (Fig. 10(c), Fig. 12) of pigs are not recommended for processed meat products due to their hardness and taint, but are used for lard production.



**Fig. 10: Pork carcass with backfat (a), belly (b), leafe fat (c) and kidney fat (d)**

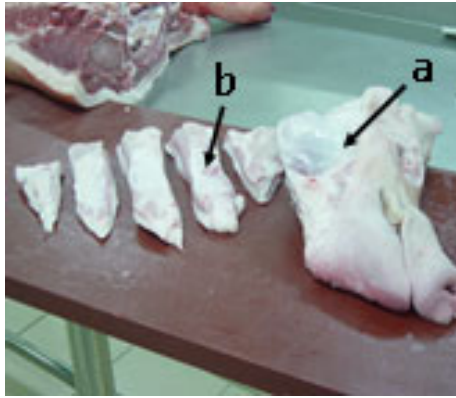


Fig. 11: Jowl fat removed from pig head (a) and cut into strips (b). Behind: Rest of pork carcass with back fat

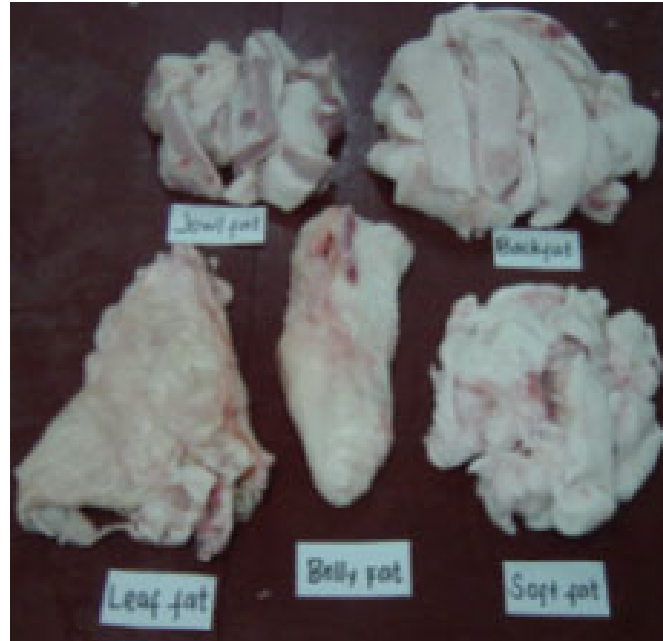


Fig. 12: All fatty tissues from the pork carcass: Jowl fat, back fat (above); leaf fat, belly and soft fat (below)

## Beef fat

Beef fat is considered less suitable for further processing than pork fat, due to its firmer texture, yellowish colour and more intensive flavour. When used for processing, preference is usually given to **brisket fat** (Fig. 13(a) and Fig. 14(b)) and other **body fats** preferably from younger animals. Such fats are used for specific processed beef products when pork fats are excluded for socio-cultural or religious reasons. Some tropical cattle breeds have a large subcutaneous fat depot in the shoulder region known as "hump". Fat is the predominant tissue of the hump together with stabilizing connective tissue and muscle meat. The **hump tissue** (Fig. 15(a)) is often cut into slices and roasted/barbecued as a delicacy or used for processed products. **Buffalo fat** has a whiter colour than beef fat and is therefore well suited for processing. The limiting factor for utilization of beef/buffalo fat is its scarce availability, as beef/buffalo carcasses do not provide high quantities of body fats suitable for the manufacture of meat products such as frankfurters, bologna etc., where amounts of fatty tissues in the range of 20% are required. However, for the manufacture of products with a lower animal

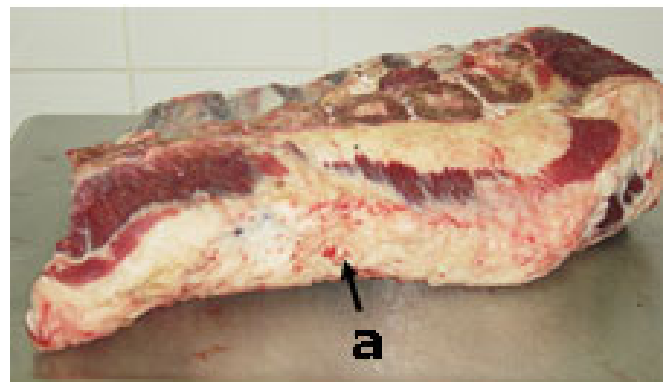
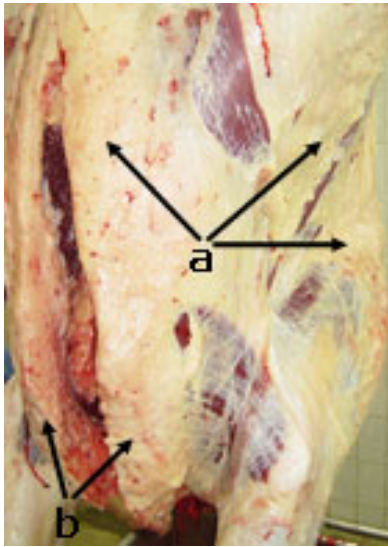


Fig. 13: Brisket fat (a) on beef cut (brisket)

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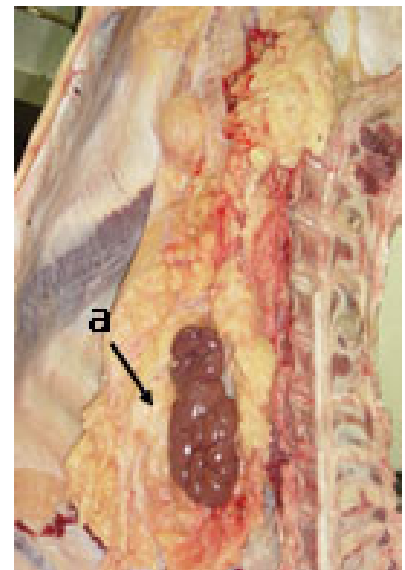
fat content, e.g. burgers, fresh sausages for frying etc., mixtures of beef and beef fat are well suited.



**Fig. 14:** Beef carcass, front part with external subcutaneous fat (a) and brisket fat (b)



**Fig. 15:** Hump with fatty tissue (a) of tropical cattle



**Fig. 16:** Kidney fat (a) in beef carcass

**Mutton fat** of adult animals is for most consumers absolutely unsuitable for consumption due to its typical unpleasant flavour and taste. Fats from lamb are relatively neutral in taste and commonly eaten with lamb chops. Lamb fat can be used as a fat source when producing Halal meat products.

### Fat from chicken

Chicken fat is neutral in taste and well suited as a fat component for pure chicken products. Chicken fat adheres as intermuscular fat to chicken muscle tissue and is processed without separating it from the lean meat (see page 56). However, the majority of chicken fat derives from chicken skin (Fig. 17, 84) with its high subcutaneous fat content. For processing, chicken skin is usually minced (see page 56) and further processed into a fat emulsion before being added during chopping.



**Fig. 17:** Chicken skin to be removed from cuts and used as fat ingredient

## The nutritional value of meat and meat products

### a. Proteins

The nutritional value of meat is essentially related to the content of high quality **protein**. High quality proteins are characterized by the content of **essential aminoacids** which cannot be synthesized by our body but must be supplied through our food. In this respect the food prepared from meat has an advantage over those of plant origin. There are vegetable proteins having a fairly high **biological value** (see page 431), for instance soy protein, the biological value of which is about 65% of that of meat. Soy protein concentrates are also very useful ingredients in many processed meat products, where they not only enhance the nutritional value but primarily the water binding and fat emulsifying capacity (see page 80).

The contractile proteins or myofibrillar proteins are quantitatively the most important (some 65%) and are also qualitatively important as they have the **highest biological value**. Connective tissues contain mainly collagen, which has a **low biological value**. Elastin is completely indigestible. Collagen is **digestible** but is devoid of the essential aminoacid tryptophan.

Blood proteins have a high content of tryptophan but are nevertheless of a lower biological value than meat due to their deficiency of the essential aminoacid isoleucine.

### b. Fats

Animal **fats** are principally triglycerides. The major contribution of fat to the diet is energy or calories. The fat content in the animal carcass varies from 8 to about 20% (the latter only in pork, see table 1). The fatty acid composition of the fatty tissues is very different in different locations. External fat ("body fat") is much softer than the internal fat surrounding organs due to a higher content of **unsaturated** fat in the external parts.

The unsaturated fatty acids (linoleic, linolenic and arachidonic acid) are physiologically and nutritionally important as they are necessary constituents of cell walls, mitochondria and other intensively active metabolic sites of the living organism. The human body cannot readily produce any of the above fatty acids, hence they have to be made available in the diet. Meat and meat products are relatively good sources, but in some plant sources such as cereals and seeds, linoleic acid is usually present at about 20 times the concentration found in meat.

In recent years it has been suggested that a high ratio of unsaturated / saturated fatty acids in the diet is desirable as this may lower the

individual's susceptibility to cardiovascular diseases in general, and to coronary heart disease in particular. There is evidence to indicate that a diet which predominantly contains **relatively saturated fats** (such as those of meat) raises the level of **cholesterol** in the blood. To avoid possible health risks from the consumption of the meat, vulnerable groups should reduce the animal fat intake.

In this context, the **"hiding" of high fat contents** in some processed meat products can be a dietary problem. Improved processing equipment and techniques and/or new or refined ingredients has made it possible to produce meat products with relatively high fat contents, which may be difficult to recognize by consumers. In particular in products like meat loaves, frankfurter type sausages or liver pate, where meat and fat are finely comminuted and the fat particles are enclosed in protein structures, the fat is difficult to detect visibly. Fat contents of up to 40% may be hidden this way, which is profitable for the producer as fat is a relatively cheap raw material. For some consumer groups, such diets are not recommended. On the other hand, there are many physically active hard working people or undernourished people, in particular in the developing world, where meat products with higher fat content may be beneficial in certain circumstances, predominantly as energy sources.



**Fig. 18: Meat loaves with different fat contents; Left lower fat (20%) and right high fat (35%)**

### c. Vitamins

Meat and meat products are excellent sources of the B-complex vitamins (see table 2). Lean pork is the best food source of Thiamine (vitamin B<sub>1</sub>) with more than 1 mg / 100 g as compared to lean beef, which contains only about 1/10 of this amount. The daily requirement for humans of this rarely occurring vitamin is 1-1.5 mg. Plant food has no vitamin B<sub>12</sub>, hence meat is a good source of this vitamin for children, as in their organisms deposits of B<sub>12</sub> have to be established. On the other hand, meat is poor in the fat soluble vitamins A, D, E, K and vitamin C. However, internal organs, especially liver and kidney generally contain an appreciable percentage of vitamin A, C, D, E and K. Most of the vitamins in meat are relatively stable during cooking or processing, although substantial amounts may be leached out in the drippings or broth. The drip exuding from the cut surface of frozen meat upon

thawing also contains an appreciable portion of B-vitamins. This indicates the importance of conserving these fractions by making use of them in some way, for example through direct processing of the frozen meat without previous thawing (which is possible in modern meat processing equipment). Thiamine (vitamin B<sub>1</sub>) and to a lesser extent vitamin B<sub>6</sub> are heat-labile. These vitamins are partially destroyed during cooking and canning.

**Table 2: Average content of vitamins in meat (micrograms per 100g)**

Food	B <sub>1</sub>	B <sub>2</sub>	B <sub>6</sub>	B <sub>12</sub>	A	C
Beef, lean, fried	100	260	380	2.7	20	1
Pork, lean, fried	700	360	420	0.8	10	1
Lamb, lean, fried	105	280	150	2.6	45	1
Veal, lean, fried	70	350	305	1.8	10	1
Pork liver, fried	260	2200	570	18.7	18000	24

#### d. Minerals

The mineral contents of meat (shown as "ash" in table 1) include calcium, phosphorus, sodium, potassium, chlorine, magnesium with the level of each of these minerals above 0.1%, and trace elements such as iron, copper, zinc and many others. Blood, liver, kidney, other red organs and to a lesser extent lean meat, in particular beef are good sources of iron. Iron intake is important to combat anaemia, which particularly in developing countries is still widespread amongst children and pregnant women. Iron in meat has a higher bio-availability, better resorption and metabolism than iron in plant products.

# PRINCIPLES OF MEAT PROCESSING TECHNOLOGY

## MEAT PROCESSING TECHNOLOGY

Meat processing technology comprises the steps and procedures in the **manufacture of processed meat products**. Processed meat products, which include various different types and local/regional variations, are food of animal origin, which contribute valuable animal proteins to human diets. Animal tissues, in the first place *muscle meat* and *fat*, are the main ingredients, besides occasionally used other tissues such as *internal organs*, *skins* and *blood* or *ingredients of plant origin*.

All processed meat products have been in one way or another physically and/or chemically treated. These treatments go beyond the simple cutting of meat into meat cuts or meat pieces with subsequent cooking for meat dishes in order to make the meat palatable. Meat processing involves a wide range of **physical and chemical treatment methods**, normally combining a variety of methods. Meat processing technologies include:

- **Cutting/chopping/comminuting** (size reduction)
- **Mixing/tumbling**
- **Salting/curing**
- **Utilization of spices/non-meat additives**
- **Stuffing/filling into casings or other containers**
- **Fermentation and drying**
- **Heat treatment** (see separate chapter page 87)
- **Smoking**

## EQUIPMENT USED IN MEAT PROCESSING

In modern meat processing, most of the processing steps can be mechanized. In fact, modern meat processing would not be possible without the utilization of specialized equipment. Such equipment is available for small-scale, medium-sized or large-scale operations. The major items of meat processing equipment needed to fabricate the most commonly known meat products are listed and briefly described hereunder.

## Meat grinder (Mincer) (see also page 301)

A meat grinder is a machine used to force meat or meat trimmings by means of a feeding worm (auger) under pressure through a horizontally mounted cylinder (barrel). At the end of the barrel there is a cutting system consisting of star-shaped knives rotating with the feeding worm and stationary perforated discs (grinding plates). The perforations of the grinding plates normally range from 1 to 13mm. The meat is compressed by the rotating feeding auger, pushed through the cutting system and extrudes through the holes in the grinding plates after being cut by the revolving star knives.

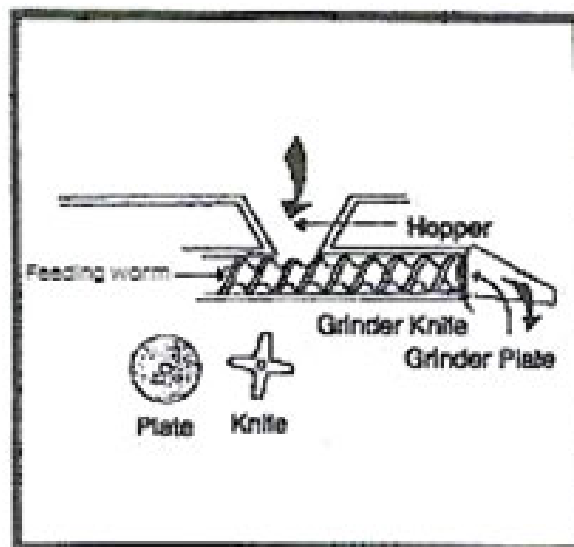


Fig. 19: Schematic drawing of grinder

Simple equipment has only one star knife and grinder plate, but normally a series of plates and rotary knives is used. The degree of mincing is determined by the size of the holes in the last grinding plate. If frozen meat and meat rich in connective tissue is to be minced to small particles, it should be minced first through a coarse disc followed by a second operation to the desired size. Two different types of cutting systems are available, the "Enterprise System" and the "Unger System":

- The "Enterprise System" (Fig. 19) is mainly used in smaller meat grinders with orifice diameters up to 98 mm and consists of one star knife, sharpened only on the side facing the disc, and one grinder plate. Hole diameters can vary from 13 to 5 mm.
- The "Unger System" (Fig. 20) is used in meat grinders with orifice diameters up to 440 mm and consists of the kidney plate, one or two star knives sharpened on both edges and one or two grinder plates.

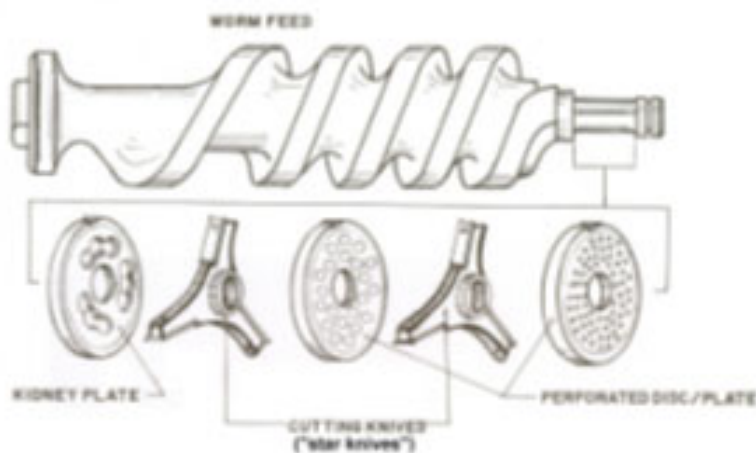


Fig. 20: Grinder: Worm feed (feeding worm/auger) and cutting set with plates and knives (system "Unger")

For a final particle size above 8 mm the recommended setting is kidney plate – star knife – grinder plate. For a final particle size <8 mm the recommended setting is kidney plate – star knife – grinder plate (13 mm) – star knife – grinder plate (6 to 1 mm) (Fig. 21).



Fig. 21: Grinder plates of different hole size, star knives and spacer rings for tightening of cutting assembly

The smallest type of meat grinder is the **manual grinder** (Fig. 22) designed as a simple stuffing grinder, i.e. meat material is manually stuffed into the feeder. For all these small machines the Enterprise cutting system is used with one star knife and one grinder plate. These machines are very common everywhere in food processing but their throughput and production capacity is limited due to the small size and manual operation.

The intermediate size meat grinder, also designed as a **stuffing grinder**, has orifice diameters up to 98 mm. It is driven by a built-in single-phase electrical motor (250 V) and available as both a table and floor model. The meat is put onto the tray and continuously fed by hand into a vertical cylindrical hole leading to the feed auger. The meat or fat is forced by its own weight into the barrel with the rotating feed auger. This type of meat grinder is the most suitable for commercial small-scale operations. Some brands use the Enterprise cutting system, others the Unger system (Fig. 23, 24).



Fig. 22: Manual grinder



Fig. 23: Grinder as table model



Fig. 24: Grinder as floor model

Large **industrial meat grinders** are driven by a three-phase electrical motor (400 V) and equipped with the Unger cutting system. The orifice cylinder diameter of this type of grinder ranges from 114 - 400 mm. Industrial grinders are either designed as stuffing grinders with either tray or hopper or as an automatic mixing grinder. The automatic mixing grinder has a big hopper and the meat falls automatically onto the mixing blades and the feeding worm (auger). The mixing blades and feeding worm can be operated independently with mixing blades rotating in both directions but the feeding worm only towards the cutting set. Most of the industrial meat grinders are also equipped with a device for separating tendons, bone particles and cartilage.

### **Bowl cutter (bowl chopper)** (see also page 303)

The bowl cutter (Fig. 25, 26, 28, 29) is the commonly used meat chopping equipment designed to produce small or very small ("finely comminuted") lean meat and fat particles. Bowl cutters consist of a horizontally revolving bowl and a set of curved knives rotating vertically on a horizontal axle at high speeds of up to 5,000 rpm. Many types and sizes exist with bowl volumes ranging from 10 to 2000 litres. The most useful size for small- to medium-size processing is 20 to 60 litres. In bigger models bowl and knife speed can be regulated by changing gears. Bowl cutters are equipped with a strong cover. This lid protects against accidents and its design plays a crucial role in the efficiency of the chopping process by routing the mixture flow. Number, shape, arrangement, and speed of knives are the main factors determining the performance of the cutter (see page 304). Bowl cutters should be equipped with a thermometer displaying the temperature of the meat mixture in the bowl during chopping.



**Fig. 25: Small 20 litre bowl cutter, single-phase motor**



**Fig. 26: Bowl cutter assembled with 6 knives**

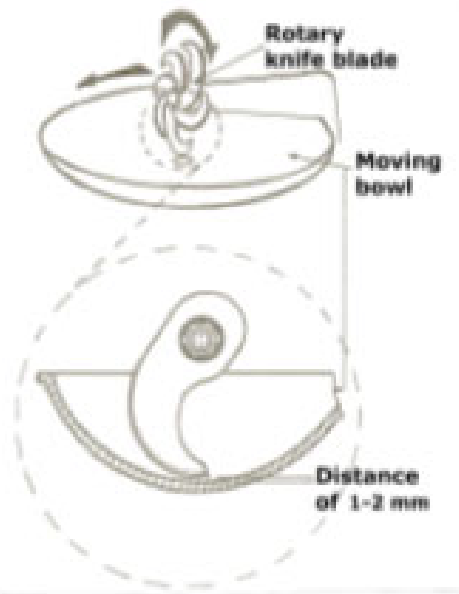


Fig. 27: Bowl cutter, schematic



Fig. 29: Bowl cutter–grinder combination (twin model) with bowl cutter (60 litres capacity) and meat grinder (114 mm orifice diameter)



Fig. 28: Bowl cutter filled with meat for chopping



Fig. 30: Vacuum cutter; lid can be hermetically closed for vacuum treatment of batter in the bowl

Modern large scale bowl cutters may have devices to operate under a vacuum (Fig. 30), which helps to improve colour and texture of the meat products by keeping oxygen out of the meat mixes and avoid air pockets. Cutter knives should be adjusted to a distance of 1-2 mm from the bowl (Fig. 27) for optimal cutting (check the manufacturers recommendations for each model). Most of the large and high-speed bowl cutters are equipped with mechanical discharger devices for emptying the cutter. The process of chopping in a bowl cutter is used for producing fine comminuted products such as frankfurters, bologna, liver sausage etc., and enables processors to offer a much wider range of products.

## Filling machine ("sausage stuffer") (see also page 306)

These machines are used for filling all types of meat batter in containers such as casings, glass jars, cans etc. The most common type of filling machine in small and medium size operations is the piston type. A piston is moved (Fig. 31) inside a cylinder forcing the meat material through the filling nozzle (funnel, stuffing horn) into the containers. Piston stuffers are either attached to the filling table (Fig. 32; manual) or designed as floor models (Fig. 33; hydraulic). In small-scale operations manual stuffers are usually sufficient, sometimes even simple hand-held funnels are used (Fig. 412) to push meat mixes into casings.

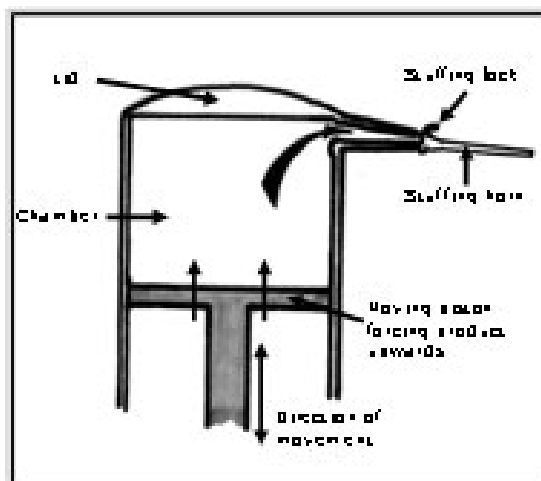


Fig. 31: Piston stuffer, schematic

manually sufficient, sometimes even simple hand-held funnels are used (Fig. 412) to push meat mixes into casings.



Fig. 32: Manual piston stuffer (10 litres)



Fig. 33: Piston stuffer (20 litres) with different size filling funnels

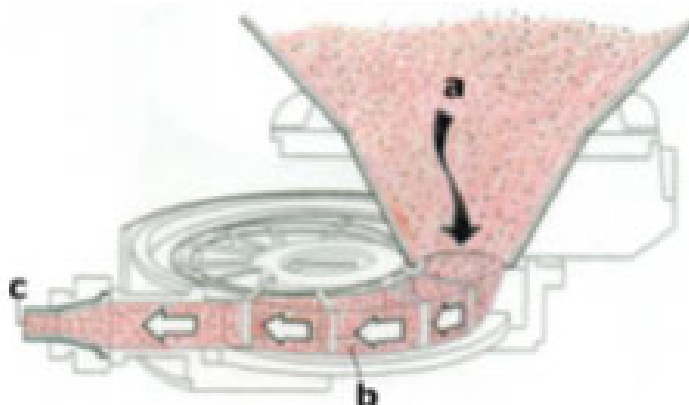


Fig. 34: Principle of continuous stuffer (can also be operated with vacuum)  
 a = Hopper (recipient for meat mix), b = Rotating transport segments for meat mix  
 c = to filling nozzle; pink colour = meat mix (transport flow)

Modern filling machines for larger operations are designed as continuous vacuum stuffers (Fig. 34). During the filling process a substantial part of the enclosed air is removed from the product, which helps to improve colour and texture of the finished products. These models are usually equipped with a portioning and twisting device and have a casing grip device attached for filling of "shirred" (folded) uncut collagen and plastic casings. This type of continuous filling equipment is relatively expensive and are thus not used in small- to medium-size operations.

### Clipping machine

Clipping machines place small aluminium sealing clips on the sausage ends and replace the manual tying of sausages. They can be used for artificial or natural casings. Clipping machines can also be connected to filling machines. Such machines work with so called casing brakes, which are devices for slow release of the shirred casings from the filling horns ensuring tight filling. Then the filled casing segments are clipped in portions. So called double clipping machines place two clips next to each other, which ensures that the individual sausage portions remain clipped on both ends and easy separation of the sausage portions is possible. When using shirred casings (see page 263), the time consuming loading of pre-cut casings is no longer necessary. Wastage of casings can be reduced to a minimum by tight filling and leaving only as much casing for the sausage end as needed for the placing of the clips.



**Fig. 35: Manually operated sausage clipping machine with clip rails (left)**

Clipping machines are mainly used in larger operations and in most cases operated by compressed air. For medium-scale operations manually operated hand clippers are available (Fig. 35).

### Smokehouses (see also page 310)

Simple smokehouses are used for smoking only (Fig. 36, 37). In **traditional** and small-scale operations the most common methods of smoke generation include burning damp hardwood sawdust, heating dry sawdust or heating pieces of log. But technological progress has changed the **smoke generation** and application techniques. Methods used in **modern** meat processing include the following:

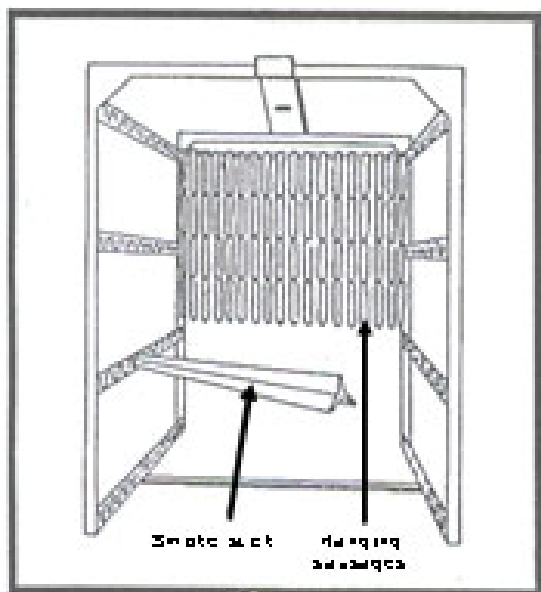


Fig. 36: Arrangement of sausages for smoking inside smokehouse, schematic



Fig. 37: Small-scale smokehouse (sawdust is placed on the smouldering tray)

### Burning/smouldering of saw dust (Fig. 38)

In modern smokehouses (1), smoke generation takes place outside the smoking chamber in special smoke generators with electrical or gas ignition (4). Separate smoke generators allow better control of the quantity and temperature of the smoke produced. The sawdust or chip material (3) is moved from the receptacle to the burning zone (4) by a stirrer or shaker (3). It is ignited by means of an electrically heated plate or by gas flame. A smoke stripper, which is basically a cold water spray, can be placed in the initial part of the smoke pipe and serves to increase the purity of the smoke as undesirable substances are washed out. Smoke with a high degree of desirable smoke components can be obtained in the low temperature range of thermal destruction of saw dust beginning at around 230°C and not exceeding 400°C. The smoke is conveyed directly from the generator to the smoking chamber (Fig. 38(1), 41) via a smoke pipe (2). The burned sawdust is collected at the bottom (5).

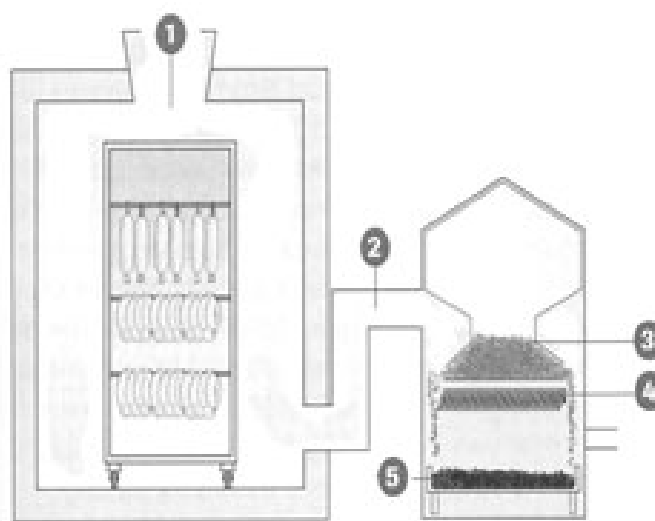


Fig. 38: Smokehouse with generator for sawdust smouldering

### Smoke generation through friction (Fig. 39)

Timber (3), which is pressed (1) against a fast-rotating steel drum (4) results in pyrolysis of the wood in the favourable temperature range of 300°C to 400°C. The flameless, light, dense and aromatic smoke contains a large proportion of desirable smoking substances and a low proportion of tars. The smoke is conveyed (2) into the smoking chamber. The creation of smoke can be commenced and completed in a matter of seconds. The operation of this type of smoke generators is usually carried out in a discontinuous manner. The smoke quantity and quality can be regulated by changing the speed and time of rotation. As this type of smoke can be produced at relatively low temperatures, it does not carry high amounts of hazardous substances such as benzopyrene (see page 40).

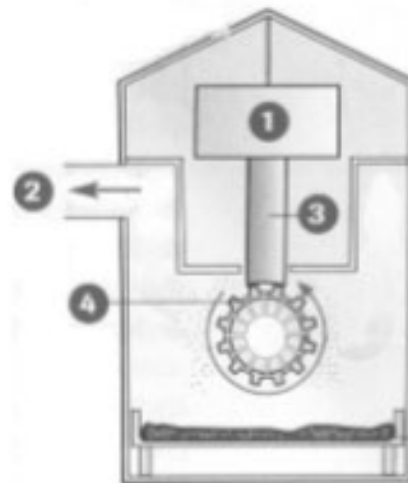


Fig. 39: Friction smoke generator

### Smoke generation through steam (Fig. 40)

Overheated steam (3) at approximately 300°C is injected into a compact layer of sawdust (4), which causes thermal destruction of the wood and smoke is generated. This method allows the control of smoke generation temperature by choosing the adequate steam temperature. Impurities in the smoke caused by particles of tar or ash are minimal. The steam-smoke mixture condensates extremely quickly and intensively on the surface and inside the sausage products and produces the desired smoking colour and flavour. No connection to the chimney is required as smoke particles not entering the products settle down in the condensing steam. The condensed water is conducted to the effluent system. Other details of the system are: Hopper and conveyer for sawdust (1,2), smoke duct to smoking chamber (5), ashes (6).

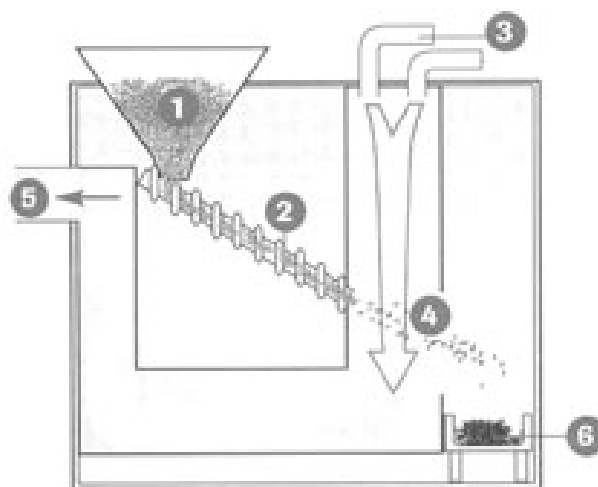


Fig. 40: Unit for generation of smoke by steam

## Combined equipment

Modern facilities can combine smoking, cooking and cooling operations for meat products in one continuous process. By means of automatic stirring systems processing parameters such as smoke generation, temperature (up to 100°C) and relative humidity (up to 100%) required to dry, smoke, or steam-cook any type of product, can be pre-set. With additional refrigerated units installed in the smokehouse, it is also possible to use it as a fermenting/ripening room for the first crucial steps in production of fermented sausages or raw ham products, where air temperature and air humidity have to be accurately controlled (see page 123, 177).



**Fig. 41:** Small smokehouse, inside view, air/smoke circulation forced by extraction fan on top (arrow) and re-circulated through openings in double jacket side wall (arrow)



**Fig. 42:** Smokehouse with sausages ready for smoking

## Brine injector

This equipment serves for the injection of brine into meat. Brine is water containing dissolved salt and curing substances (nitrite) as well as additives such as phosphates, spices, sugar, carrageenan and/or soy proteins (see page 179). The injection is done by introducing pointed needles into the muscle tissue. Brine injection is mainly used for the various types of ham, bacon and other whole muscle products.

Brine injectors are available in different sizes from manually operated single-needle devices (Fig. 43, 44) for small-scale operations to semi-automated brine injectors with up to 32 needles and more (Fig. 45, 46). In large machines the quantity of brine injected into the fresh meat can be determined by pre-setting of pressure and speed. It is very important

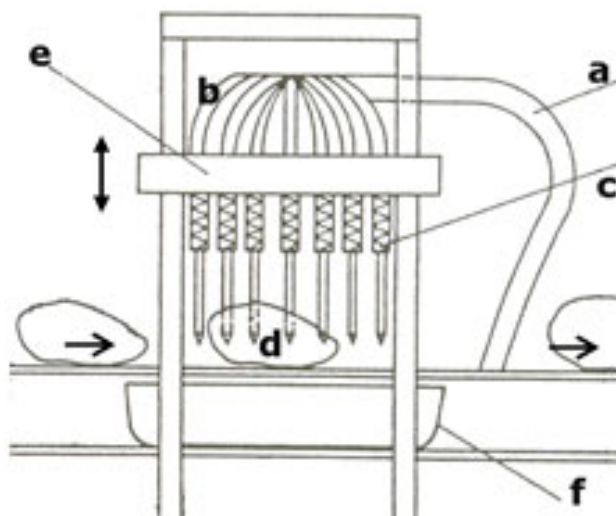
that all parts of the brine injectors are thoroughly cleaned after every working session and disinfected regularly. Before the injector is used again all hoses and needles should be rinsed with warm water as particles left in the system can block the needles. Absolute cleanliness is necessary as microorganisms remaining in the system would be injected deep into the meat pieces during the operation.



**Fig. 43: Brine injectors, pump driven, manually operated, with single needle (left) and multi needle device (right)**



**Fig. 44: Manual pump type injector (left), syringe type injector (right)**



**Fig. 45: Multi-needle injector, schematic**  
 a - Main brine supply pipe, b - Brine distribution pipe, c - Injection needle, d - Meat piece to be injected, e - Sliding needle holder, f - Excess brine collection pan



**Fig. 46: Multi-needle injector, semi-automated**

## Tumbler or Massager

Tumblers (Fig. 47) are used for the processing of meat products such as whole-muscle or reconstituted hams. Such machines resemble in principle a drum concrete mixer. A rotating drum with steel paddles inside slowly moves the meat pieces thus causing a mechanical massaging effect. This mechanical process is assisted by the addition of salt and phosphates to achieve equal brine distribution and liberates muscular protein from the meat tissue (protein extraction). The semi-liquid protein substances join the meat pieces firmly together during later heat treatment (see page 184, 185). For hygienic reasons it is important to place the tumbler below 10°C to avoid excessive microbial growth during lengthy tumbling times (more than 4 hours or even over night). In specific cases it is recommended that the tumbler should be operated refrigerated (Fig. 48, 49) or inside a cold room below -1°C, as these temperatures are best to extract as much soluble protein as possible from the muscle meat.

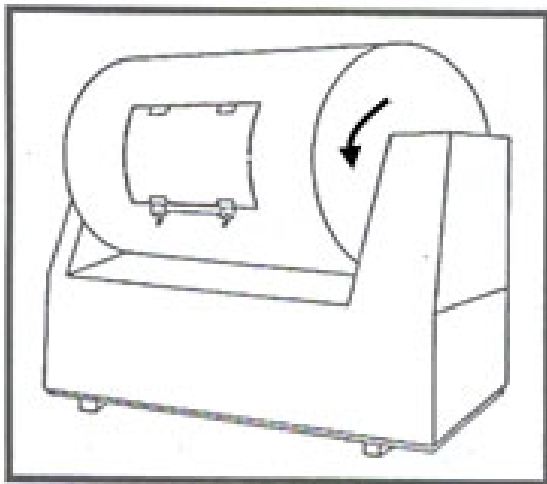


Fig. 47: Tumbler. schematic



Fig. 48: Tumbler with double jacket for refrigeration and vacuum pump/motor device



Fig. 49: Tumbler inside mobile refrigerated housing

## Vacuum packaging machine

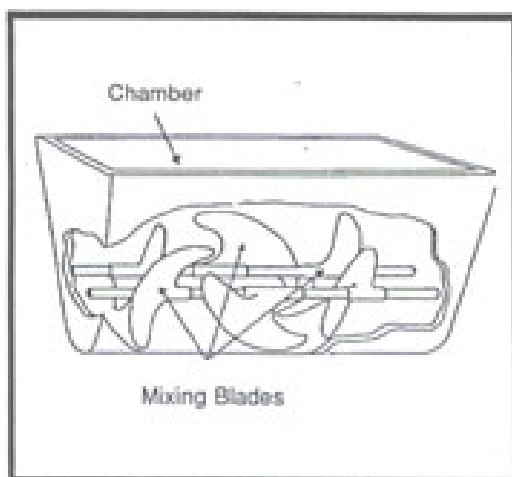
For vacuum packaging the meat product has to be placed into a vacuum bag (multi-layer synthetic bag, see page 270). Air is removed from the bag by means of the vacuum packaging machine (Fig. 50) and the bag then sealed (see page 273). Special vacuum packaging machines can operate with so called gas-flushing, where a mixture of gas is injected after evacuating the air. Such protective gas atmospheres inside the product package inhibit bacterial growth and stabilize the meat colour. The gas mixtures usually contain CO<sub>2</sub> and N<sub>2</sub> (see page 275).



**Fig. 50: Vacuum packaging machine (table model)**

## Mixer / blender

Mixers are used to blend meat and spices, or coarse and finely chopped meat. The machine generally consists of a rectangular or round bottom vessel through which two parallel shafts operate (Fig. 51). Various paddles are mounted on those shafts to mix the meat. The mixer is discharged through tilting by 90 degrees. Some mixers are designed as vacuum mixers (Fig. 52), as the mixing under vacuum (exclusion of oxygen) has advantages for the development of desirable product colour and texture.



**Fig. 51: Blender, schematic**



**Fig. 52: Blender with lid for hermetic closure for vacuum treatment; can be declined for emptying**

## Emulsifying machine (colloid mill)

The emulsifier (Fig. 53, 54) serves for the preparation of very fine meat emulsions. Its functional parts are a perforated plate, attached to which two edged blades are rotating (rotor blade) (Fig. 55). Next to the blades there is a centrifugal pump that forces the pre-ground meat through the perforated plate. Most emulsifiers are vertical units. Compared to the bowl cutter the emulsifier operates at much higher speed, producing a finer emulsion-like mix. The emulsifier is also perfectly suited to produce semi-processed products such as pig skin emulsions (see page 32).

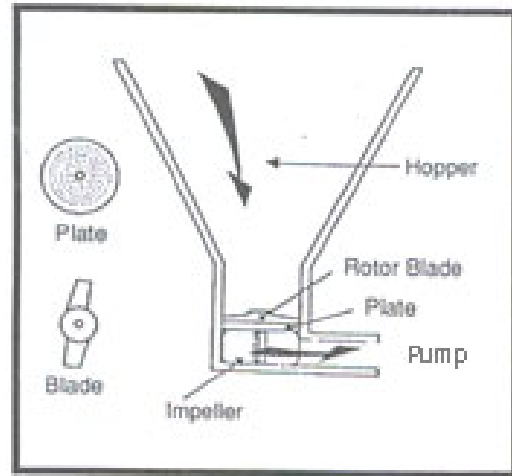


Fig. 53: Emulsifying machine, schematic



Fig. 54: Emulsifying machine (top down view)



Fig. 55: Emulsifying machine (plate and rotating blade)

## Ice flaker

In these machines (Fig. 56) ice flakes are continuously produced from potable water. Ice is needed in meat processing for some types of meat products. Water, added in the form of ice, is an important ingredient in order to enhance protein solution (see page 128) and to keep the temperature of the meat batter low. Ice flakers with in-built UV-water-disinfection device are available for areas with unsafe water supply.



Fig. 56: Ice flaker with storage compartment

## Frozen meat cutter

The purpose of cutting frozen meat blocks into smaller pieces is to make frozen meat suitable for immediate comminuting in grinders, bowl cutters etc. without previous thawing. There are two types of machines for the cutting of frozen meat blocks, working either with knives cutting in vertical direction (guillotine principle) or using rotating drums with attached sharp knives. In the guillotine-type machines a knife head is driven hydraulically and even the hardest frozen products can be cut into small pieces, either meat cubes or meat strips. Rotary frozen meat cutters (Fig. 57) operate according to the principle of carving out particles from the frozen meat blocks. The rotary drums can be equipped with knives capable of cutting out pieces of frozen meat from large fist-size to small chip-size.



**Fig. 57: Frozen meat cutter with rotating round knives for cutting out pieces/chips from frozen meat blocks**

## MEAT PROCESSING TECHNOLOGIES – STANDARD PRACTICES

Meat processing technologies include on the one hand purely technical processes such as

- Cutting, chopping, comminuting
- Mixing, tumbling
- Stuffing/filling of semi-fabricated meat mixes into casings, synthetic films, cans etc.
- Heat treatment

On the other hand, chemical or biochemical processes, which often go together with the technical processes, are also part of meat processing technology such as

- Salting and curing
- Utilization of spices and additives
- Smoking
- Fermentation and drying

These processes are described hereunder and in the following chapters.

## 1. Cutting (reducing meat particle size)

There are five methods of mechanical meat cutting for which specialized machinery is used:

### **Mincing (grinding) of lean and fatty animal tissues** (Fig. 58)

Larger pieces of soft edible animal tissues can be reduced in size by passing them through meat grinders. Some specially designed grinders can also cut frozen meat, others are equipped with devices to separate "hard" tissues such as tendons and bone particles from the "soft" tissues (minced muscle meat particles) (see page 18, 301).

### **Chopping animal tissues in bowl cutter (discontinuous process)** (Fig. 59)

Bowl cutters are used to chop and mix fresh or frozen lean meat, fat (and/or edible offal, if required) together with water (often used in form of ice), functional ingredients (salt, curing agents, additives) and extenders (fillers and/or binders) (see page 20, 111, 137, 151, 157)



**Fig. 58: Mincing of raw meat material for processed meat products in meat grinders**



**Fig. 59: Chopping of meat mixture in bowl cutter; lid opened after finalizing chopping, cutter knives visible**

### **Chopping animal tissues in emulsifying machines (continuous process)**

The animal tissues to be emulsified must be pre-mixed with all other raw materials, functional ingredients and seasonings and pre-cut using grinders or bowl cutters. Thereafter they are passed through emulsifiers (also called colloid mills) in order to achieve the desired build-up of a very finely chopped or emulsified meat mix (see page 30).

### Frozen meat cutting

Boneless frozen meat blocks can be cut in slices, cubes or flakes by frozen meat cutters or flakers. The frozen meat particles (2-10 cm) can be directly chopped in bowl cutters without previous thawing thus avoiding drip losses, bacterial growth and discoloration which would happen during thawing (see page 31). For small operations the manual cutting of frozen meat using cleavers or axes is also possible.

### Cutting of fatty tissues

Back fat is cut in cubes of 2-4 cm on specialized machines to facilitate the subsequent chopping in cutters/emulsifiers. In small-scale operations this process can be done manually.

## 2. Salting / curing

**Salting** – Salt (sodium chloride NaCl) adds to the **taste** of the final product. The content of salt in sausages, hams, corned beef and similar products is normally 1.5-3%. Solely common salt is used if the cooked products shall have a greyish or greyish-brown colour as for example steaks, meat balls or “white” sausages (see box page 33). For production of a red colour in meat products see “Curing” (page 34).

### Chemical aspects of salting

The water **holding capacity** of meat can be increased with the addition of salt up to a concentration of about **5%** in lean meat and then decreases constantly. At a concentration of about 11% in the meat, the water binding capacity is back to the same level as in fresh unsalted meat.

Sodium chloride has only a very low capacity to destroy microorganisms, thus almost **no bacteriological effect**. Its **preserving power** is attributed to the capability to bind water and to deprive the meat of moisture. The water loosely bound to the protein molecules as well as “free” water will be attracted by the sodium and chloride ions causing a reduction of the water activity ( $a_w$ ) (see page 323) of the product. This means that less water will be available and the environment will be less favourable for the growth of microorganisms. Bacteria do **not** grow at a water activity **below 0.91**, which corresponds to a solution of **15g NaCl/100 ml water** or about 15% salt in the product. These figures explain how salt has its preservative effect. Such salt concentrations (up to 15%) are too high for palatable food. However, for the preservation of natural casings this method is very useful

Heat treatment of meat salted with NaCl results in conversion of the red meat pigment **myoglobin** ( $Fe^{+2}$ ) to the brown **metmyoglobin** ( $Fe^{+3}$ ). The colour of such meat turns brown to grey (see Fig. 60, 61).

Besides adding to flavour and taste, salt also is an important functional ingredient in the meat industry, which assists in the extraction of soluble muscle proteins. This property is used for **water binding** and **texture** formation in certain meat products (see page 129, 184).

The **preservation** effect, which is microbial inhibition and extension of the shelf-life of meat products by salt in its concentrations used for food (on average 1.5-3% salt), is low. Meat processors should not rely too much on this effect (see box page 33) unless it is combined with other preservation methods such as reduction of moisture or heat treatment.

**Curing** – Consumers associate the majority of processed meat products like hams, bacon, and most sausages with an attractive pink or red colour after heat treatment. However experience shows that meat or meat mixes, after kitchen-style cooking or frying, turn brownish-grey or grey. In order to achieve the desired red or pink colour, meat or meat mixes are salted with common salt (**sodium chloride NaCl**), which contains a small quantity of the curing agent **sodium nitrite (NaNO<sub>2</sub>)**. Sodium nitrite has the ability to react with the red meat pigment to form the heat stable red curing colour (for details see box page 35, 68). Only very small amounts of the nitrite are needed for this purpose (Fig. 60, 61, 88).



**Fig. 60: Pieces of cooked meat (pork)**  
4 pieces with common salt only (right) and 3 with common salt containing small amounts of nitrite (left)



**Fig. 61: Two sausage cuts**  
One produced with salt only (right) and the other with salt and small amounts of nitrite (left)

Nitrite can be safely used in tiny concentrations for food preservation and colouring purposes. Traces of nitrite are not poisonous. In addition to the reddening effect, they have a number of additional beneficial impacts (see below) so that the meat industries widely depend on this substance. Levels of 150 mg/kg in the meat product, which is 0.015%, are normally sufficient.

To reduce the risk of overdosing of nitrite salt, a safe approach is to make nitrite available only in a homogeneous mixture with common salt generally in the proportion **0.5% nitrite** and the balance of **sodium chloride (99.5%)**. This mixture is called **nitrite curing salt**. At a common dosage level of 1.5-3% added to the meat product, the desired salty flavour is achieved and at the same time the small amount of nitrite needed for the curing reaction is also provided. Due to the sensory limits of salt addition (salt contents of 4% are normally not exceeded), the amounts of nitrite are kept low accordingly.

### Chemical and toxicological aspects of curing

In meat or meat mixes to be cured the nitrite curing salt must be evenly distributed (relevant techniques see page 37, 38, 39, 134, 173, 179)). During mixing the nitrite is brought in close contact with the muscle tissue and its red meat pigment, the myoglobin. Due to the acidification in meat after slaughter (see page 4), the pH of such meat or meat mixes is always below 7, which means slightly acidic. The acidity may be enhanced through curing accelerators such as ascorbic acid or erythorbate (see page 37, 68).

Nitrite ( **$\text{NaNO}_2$** ), or rather nitrogen oxide, NO, which is formed from nitrite in an acid environment, combines with **myoglobin** to form **nitrosomyoglobin**, a bright red compound. The nitrosomyoglobin is **heat stable** i.e. when the meat is heat treated the bright red colour remains. The addition of nitrite curing salt in quantities of approximately 2%, which is the usual salt level, generates a nitrite content in the meat products of approximately 150ppm (parts per million or 150 mg/kg). This nitrite content is **not toxic** for consumers. Upon reaction of the nitrite with the myoglobin (which is the genuine curing reaction), there will be on average a residual level of nitrite of 50-100ppm remaining in the product. In any case the amount of residual nitrite in the finished product should not exceed 125ppm. The maximum ingoing amount for processed meat products is normally up to 200mg/kg of product (Codex Alimentarius, 1991).

Apart from its poisoning potential (which is unlikely when using nitrite curing salt), there is a debate concerning the possible health hazards of nitrite curing as under certain conditions nitrite can form **nitrosamines**, some of which can be carcinogenic in the long term. However, nitrosamines can only be found in strongly cooked or fried meat products which were previously cured with nitrite. Fresh meat for cooking (see page 90) and fresh burgers or sausages for frying (see page 103) do usually not contain nitrite but salt only. Hence the risk of formation of nitrosamines does not exist in such products. One product, where such conditions may be met, is bacon. Keeping the residual nitrite content low in bacon minimizes the risk of formation of nitrosamines.

Sodium or potassium nitrate (Na/KNO<sub>3</sub>) ("saltpetre") may also be used for curing but it is limited to certain dry cured products such as raw hams, which require long curing and aging periods. Nitrate must be broken down by bacteria to nitrite, which is the substance to react through its NO with the muscle pigment myoglobin. The bacterial process is rather slow and time consuming. As most products require an immediate curing effect, the nitrite is the substance of choice in most cases and there is little use for nitrate (see also page 119).

A great deal of research has been done with regard to the utilization of nitrite and it can be said that nitrite in meat products is safe if basic rules (see box page 35) are adhered to. Nitrite is now recognized a substance with multifunctional beneficial properties in meat processing:

- The primary purpose of nitrite is to create a **heat resistant red** colour in a chemical reaction with the muscle pigment, which makes cured meat products attractive for consumers.
- Nitrite has a certain **inhibitory effect on the growth of bacteria**. This effect is particularly pronounced in canned meat products which are usually stored without refrigeration, where small numbers of heat resistant bacteria may have survived but their growth is inhibited by the presence of nitrite (see also page 77).
- Nitrite has the potential of **attributing a specific desirable curing flavour** to cured products.
- In the presence of nitrite **fats are stabilized** and rancidity in meat products retarded i.e., an antioxidant effect.

Many attempts have been made to replace nitrite by other substances, which would bring about the same beneficial effects as listed above. Up to now no alternative substance has been found. As the above desirable effects are achieved with extremely low levels of nitrite, the substance can be considered safe from the health point of view. Currently the known advantages of nitrite outweigh the known risks.

### **Curing of chopped/comminuted meat mixtures**

Curing is applied for most **chopped meat mixtures** or **sausage mixes** for which a reddish colour is desired. The curing agent nitrite is added in **dry form** as nitrite curing salt (Fig. 62). The reaction of nitrite with the red meat pigment starts **immediately**. Due to homogenous blending the meat pigments have instant contact with the nitrite. Higher temperatures during processing, e.g. "reddening" of raw-cooked type sausages at 50°C or scalding/cooking of other products at 70-80°C, accelerate the process.