Processed Meats

Second Edition

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PROCESSED MEATS

Second Edition

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To W. E. Kramlich, who was largely responsible for bringing the earlier edition to fruition, but was unable, owing to the press of business responsibilities, to contribute to this revision

Contents

Preface

This book has been updated and expanded to give more complete coverage than the earlier edition.

Like the earlier edition, it emphasizes basic scientific principles involved in production of processed meat and poultry products. In addition, many product formulations and processing procedures that have been tested under commercial conditions are included.

Intended as a university text for advanced undergraduate and graduate students enrolled in the meat processing course, it is hoped that this book will also prove useful as a reference book to industry and government scientists and researchers engaged in or associated with meat and poultry processing.

A. M. Pearson
F. W. Tauber†

†Deceased

1

Introduction to Meat Processing

Meat processing as discussed in this text includes all processes utilized in altering fresh meat except for simple grinding, cutting, and mixing. In the broadest sense, this includes curing, smoking, canning, cooking, freezing, dehydration, production of intermediate-moisture products, and the use of certain additives such as chemicals and enzymes. However, the definition excludes cutting, grinding, and packaging of fresh meats in retail stores and in homes. In this way, the definition differentiates between (1) those processes that enter into the preservation and manufacturing of meat products, and (2) those that alter the form of fresh meat in preparation for consumption.

HISTORICAL

The origin of meat processing is lost in antiquity but probably began when primitive man first learned that salt is an effective preservative, and that cooking prolongs the keeping quality of fresh meat. In any case, meat processing had its origin before the dawn of civilization. The ancient Egyptians recorded the preservation of meat products by salting and sun-drying. The early Romans are credited with being the first to use ice and snow as a means of preserving food. Modern food processing traces its origin to the development of canning for which Nicholas Appert, a chef, received an official commendation from the French government in 1809. Since that time, advances in technology have continued to change processing methods.

Newer methods of meat preservation include (1) chemical additives, (2) development of intermediate-moisture foods, (3) freeze dehydration, (4) enzyme treatments, and (5) irradiation. Increased scientific information and technological advances have greatly changed many processing methods. Among examples of this are the developments that have led to commercial freezing and new techniques of curing and smoking.

Many of the revolutionary new developments came as a consequence of war. The early American Indians probably developed jerky (thin dried strips of meat) and pemmican (a mixture of dry and semidry meat pounded together with dried fruits and vegetables covered with

A. M. Pearson et al., *Processed Meats*

melted fat) as sources of high-energy, light-weight foods for use while on the warpath. Although the origins of jerky and pemmican are not well documented, the development of canning can be traced definitely to the need for stable foods during the Napoleonic War in France. Freezing of meat on a large scale also was accelerated by World War I, while irradiation, freeze dehydration, and antibiotic preservation were outgrowths of World War II. Although many of these developments might have occurred anyway, the impetus for usage was the need to meet the requirements of a well-fed, well-clothed army. Meat, being a morale builder, has played a central role in almost all military-oriented food research. Intermediate-moisture foods are presently being developed to meet current military needs for a safe, stable, and acceptable product that does not require refrigeration.

PURPOSES OF MEAT PROCESSING

The original basis for meat processing was preservation by inhibiting or deterring microbial decomposition. Early meat-processing developments were based on this concept. In addition to preventing spoilage, preservation also resulted in flavorful and nutritious products. With the advent and almost universal availability of refrigeration, meat processing has now taken on the additional aspects of providing both convenience and variety. Today, processed meats are regarded highly because of these two characteristics. Thus, processed meats are frequently purchased because of convenience and the variety imparted to the meat portion of the diet.

Meat processing has resulted in major changes in the demand for certain cuts of meat. At the turn of the century, pork was the only meat processed in quantity. Today, beef and mutton are also used in large amounts in a variety of processed products. Recent advances have resulted in the use of large quantities of boneless poultry meat in processed meat products. Although boneless turkey and chicken rolls have been on the market for 20–30 years, production of poultry frankfurters and other cured poultry meat products has increased dramatically in the past few years. Boneless comminuted poultry meat derived from low-priced cuts (backs, necks, and wings) is not only used to extend the red meats utilized in frankfurters, but are now used to produce chicken and turkey frankfurters without any red meats. Many other types of sausages containing poultry meat are being widely marketed today. Salami made from poultry meat and turkey hams has been well accepted. It is probable that usage of poultry meat for production of processed meats will continue to increase in volume as long as the price remains favorable in relation to red meats. Approval for the use of deboned red meats will also undoubtedly result in large quantities of these raw materials being incorporated into processed meat items.

IMPORTANCE OF MEAT INDUSTRY

The total value of shipments from meat packing plants amounted to $31.21 billion in 1977 according to the Census of Manufactures, an increase of 36% over 1972. The increased value added by the manufacturers was $4.01 billion in 1977, an increase of 35% over 1972. The number of employees in 1977 amounted to 146,200, a decrease of 7% from 1972. Sausages and other prepared meat shipments were valued at $8.46 billion in 1977, an increase of 83% over 1972. The total number of employees by this segment of the meat industry consisted of 65,000, an increase of 11% over 1972.

In 1981, a total of 39.04 billion lb of meat (dressed weight) was slaughtered in the United States, with all but 362 million lb being killed by commercial meat packers. Total cash receipts from the sales of livestock amounted to $39.2 billion. Total sales for the meat packing industry amounted to $49.4 billion. This resulted in a net return of only 0.6% of total sales. The earnings as a percentage of sales are shown in Table 1.1 and demonstrate that the earnings to sales ratio was 0.6% for 39 beef packers compared to 0.7% for 42 pork packers, probably reflecting somewhat more processing by the latter group. The ratios of earnings to sales are much lower than that for all manufacturing, where the ratio mean amounted to 4.7% in 1981. The earnings as a percentage of sales also showed the meat packing industry to be much lower (3.6%) than that for all manufacturing (6.5%). The earnings to net worth ratio was also considerably lower for the meat packing industry in comparison to all other manufacturing, being 7.5 versus 13.3%, respectively. However, the sales to assets ratio was higher for the meat packing industry than for all other manufacturing, amounting to 5.9 in comparison to 1.4%, respectively.

Increased prices for lean meats have also altered processing practices and encouraged the incorporation of increased percentages of less expensive fat. Similarly, high meat prices and technological advances

TABLE 1.1. Financial Ratios of Meat Packers Compared with All Other Manufacturers in the United States (1981)

Industry Segment	Number of companies	Earnings as % of Sales	Earnings as % of Assets	Earnings as % of Net worth	Sales to assets ratio
Meat packing industry	—	0.6	3.6	7.5	5.9
Beef packers[a]	28	0.6	4.8	10.7	8.5
Pork packers[a]	39	0.7	3.0	6.1	4.5
Total manufacturing	—	4.7	6.5	13.3	1.4

Source: American Meat Institute (1982B).

[a] Defined as companies whose slaughter of the designated species accounted for over 75% of the total liveweight slaughtered.

in manufacturing vegetable proteins, such as spun soy protein, have resulted in the development of meat substitutes. It seems likely that lower-cost vegetable proteins will be used as meat extenders in combination products containing meat and vegetable proteins. Development of synthetic meat flavors may result in entirely new kinds of meat substitutes which could alter the conventional meat industry.

The processed meat industry now accounts for approximately 30% of the total volume of the meat industry. Long-term trends indicate that meat processing will maintain its importance and encompass a large portion of total meat production. The profitability and new technological advances will probably affect the rate and ultimate extent to which meat is processed.

The meat-processing industry tends to be localized near centers of consumption, whereas slaughterers and large packers tend to be located close to livestock-producing areas. Location, however, may be dictated by other factors, such as transportation and zoning ordinances. Convenience to transportation centers and the availability of raw materials may determine the location of meat-processing plants to a considerable extent.

MAGNITUDE AND RELATIVE VALUE

There are two sources of information relating to the quantity and value of processed-meat shipments: (1) the meat-inspection program conducted by the U.S. Department of Agriculture, and (2) the Census of Manufactures, Bureau of the Census, U.S. Department of Commerce. The federal meat-inspection program collects volume data in pounds on a weekly basis from manufacturing plants under Federal inspection. It has been estimated that in 1981 about 94% of total shipments were included in federal inspection reports. The American Meat Institute reports are based on the data collected by the U. S. Department of Agriculture. The Census of Manufactures collects production volume and value data at 5-year intervals from all manufacturing plants. The most recent census year was 1977.

The organization and structure of the meat-packing industry are based on classifying establishments according to function. These are (1) slaughtering and processing, (2) processing, and (3) warehousing. The majority of plants engage in processing because it is usually quite profitable. Some processors maintain slaughtering operations, however, in order to have a ready supply of raw materials. Thus the combination of processing and slaughtering adds flexibility to an operation and permits better control of raw materials.

Table 1.2 shows the breakdown of the sales dollar by different categories of expenses. It also shows the costs of livestock, meat, and other raw materials, and the gross margin. Although the classification of companies does not differentiate between companies that are strictly processors and those that are strictly slaughtering livestock and sell-

TABLE 1.2. Breakdown of Sales Dollar by Types of Meat Companies (1981 data)

Item	Meat Packing Companies				Meat Processing Companies[d]
	National[a]	Regional[b]	Local[c]	All	
Cost of meat, livestock and raw material	74.2	77.0	80.0	75.1	67.0
Gross margin	25.8	23.0	20.0	24.9	33.0
Total sales	100.0	100.0	100.0	100.0	100.0
Operating Expenses (cents)					
Wages and salaries	8.6	8.3	8.2	8.5	9.3
Employee benefits	3.1	2.7	1.8	3.0	3.0
Interest	0.5	0.3	0.4	0.5	0.4
Depreciation	0.7	0.8	0.9	0.7	1.0
Rents	0.3	0.3	0.2	0.3	0.5
Taxes[e]	0.2	0.1	0.2	0.2	0.4
Supplies and containers	4.2	3.1	2.2	3.9	5.0
All other operating costs	7.2	6.2	4.6	6.8	10.2
Total other operating costs	24.8	21.8	18.5	23.8	29.8
Earnings before taxes	1.0	1.2	1.5	1.1	3.3
Income taxes	0.4	0.6	0.6	0.5	1.3
Net earnings	0.6	0.6	0.9	0.6	2.0

Source: American Meat Institute (1982A).
[a] National meat packing companies include 11 with national sales and distribution.
[b] Regional meat packing companies include 34 with regional distribution.
[c] Local meat packing companies include 44 with only local distribution.
[d] Values were taken from 63 meat processing firms.
[e] Taxes paid not including social security and income taxes.

ing fresh meat, the data show a trend of higher gross margins, a larger proportion of operating expenses for wages and salaries, and slightly higher earnings for the processing companies. Closer segregation of the companies into processors and slaughterers would unquestionably increase these differences, since processors are marketing more labor and service.

Examination of the data in Table 1.3 on the percentage breakdown of the source and disposition of income demonstrates that great variation occurs depending on the type of company. Selling and administrative costs are higher for meat processors than for meat packers where slaughtering comprises an important part of their operations. This is not surprising in view of the differences in the size of operations. Processing is not only more labor intensive, but it also tends to involve higher distribution costs involved in store-to-store servicing. Nevertheless, many processors also prefer to control their own slaughtering facilities in order to have a constant supply of raw meat available.

Table 1.3 shows the source and disposition of income for different types of meat packing companies (national, regional, and local) and for some meat processing companies. The percentage of income expended for operating costs are highest for the national packers and lowest for the local packers, who spend considerably more of their income on

TABLE 1.3. Percentage Breakdown of Source and Disposition of Income by Different Types of Companies for 1981

Company Classification[a]	No. of companies	Income (%)			Disposition of Income (%)		
		Operating	Other	Total	Non-operating charges	Dividends paid	Earnings retained
Meat Packing Companies							
National Packers	11	75.4	24.6	100.0	[b]	27.6	72.4
Regional Packers	34	67.5	32.5	100.0	4.4	19.3	76.3
Local Packers	44	36.9	63.1	100.0	[b]	13.9	86.1
Average of all meatpackers	89	71.3	28.7	100.0	1.3	24.6	74.1
Meat Processing Companies							
Meat Processing Companies	63	69.3	30.7	100.0	21.1	2.6	76.3

Source: American Meat Institute (1982A)

[a] Companies are classified as meat packers, who are involved in slaughtering and some processing, in contrast to meat processors whose main activity involves processing.

[b] Less than 0.05%

other costs. National packers paid larger dividends and retained a lower proportion of their income.

Table 1.4 compares meat packing, sausage manufacturing (including other prepared meats), poultry dressing, and poultry and egg processing plants from the standpoint of the number of companies, the number of employees, the value of shipments, and the value added by the manufacturer. Another column presents data on the percentage increase in value. Meat packing companies added 12.8% to the value of shipments as compared to 24.0% for manufacturers of processed meat. The difference between the two categories of companies would probably be larger if the comparison had eliminated all meat packers involved in any meat processing. Both poultry dressing plants and poultry and egg processing plants added a greater percentage of value than meat packing plants. Some of the higher value added is, no doubt, due to more cutting and packaging of birds by poultry slaughtering plants. The increase in poultry processing has already been discussed, and unquestionably adds greatly to the increased value of shipments from poultry processors. In total, the percentage of added value by all meat packing, sausage and meat processors, poultry slaughtering plants, and poultry and egg processors gave an average added value of 16.2% to all shipments.

Table 1.5 shows the amounts of different meat products produced under Federal meat inspection in 1981. Fresh meat comprised about 70% of the total, with processed meat products amounting to around 30% of the total. Sausages made up the largest single category of processed meat, accounting for approximately 9% of total meat production. Uncooked, cured products comprised about 8% of the total, whereas, smoked, dried, and cooked meats accounted for about the same proportion. Canned meat products amounted to nearly 4% of the total, while convenience items, including such items as pizza, meat pies and meat entrees, amounted to only about 2% of the total production. In total, processed meats account for nearly one-third of all meat consumed, which indicates the magnitude of the meat processing industry.

The data in Table 1.6 show the breakdown of consumer expenditures for meat, poultry, and fish in grocery stores. Some 48% of these expenditures were for fresh red meats and about 31% for processed meats, with the remainder of about 21% being spent for poultry and fish, including other seafoods. The data clearly demonstrate the importance of processed meats to the total. Although fish and poultry make up a sizeable proportion of the total, part of these are also further processed.

RELATIVE IMPORTANCE OF PROCESSED MEATS

Processed meats accounted for over 30% of all meat production by federally inspected plants in 1981, or about 17.9 billion lb (Table 1.7).

TABLE 1.4. Comparison of Meat Packing, Sausage Manufacturing, Poultry Dressing, and Poultry and Egg Processing Plants from Standpoint of Percent Value Added During Manufacturing

Kind of plant operation	Number of companies	Number of employees (1,000)	Value of shipments ($million)	Value added by manufacturer ($million)	% Value added by manufacturer
Meat packing plants	2,403	146.2	31,208.2	4,010.1	12.8
Sausages and other prepared meats	1,213	65.0	8,465.4	2,039.1	24.0
Poultry dressing plants	313	86.8	5,746.1	1,236.9	21.5
Poultry and egg processing plants	124	11.1	856.6	192.0	22.4
All meat and poultry plants	3,967	309.1	46,276.3	7,478.0	16.2

Source: Census of Manufactures (1977).

TABLE 1.5. Classes, Amounts and Percentages of Different Meat Products Produced Under Federal Inspection in 1981

Classes of products	Amount (1,000 lb)	% of Total
Fresh meat—All	41,219,331	69.7
Cured meat—Not smoked or cooked	4,598,367	7.8
Smoked, dried and cooked meat	4,593,795	7.8
Sausages—All	5,036,381	8.6
Canned meat	2,213,450	3.7
Convenience meat items[a]	1,447,820	2.4
Total processed meat	17,889,813	30.3
Total all meat	59,109,144	100.0

Source: Adapted from American Meat Institute (1982B).
[a] Convenience meat items include pizzas, meat pies, and meat entrees, etc.

TABLE 1.6. Consumer Expenditures for Meat, Poultry and Fish in Grocery Stores

Item	1980 ($Million)	% of Meat, Poultry and Fish
Fresh Meat		
Beef	18,761	37.2
Veal	603	1.2
Lamb	899	1.8
Pork	3,929	7.8
Total fresh meat	24,193	48.0
Processed Meats		
Cured hams and picnics	2,323	4.6
Packaged bacon	2,001	4.0
Frankfurters	1,478	2.9
Sausages and cold cuts (except frankfurters)	7,882	15.6
Canned meat	1,903	3.8
Total Processed Meats	15,587	30.9
Frozen Meat	216	0.4
Total All Meat	39,996	79.4
Poultry		
Fresh	5,151	10.2
Frozen	1,311	2.6
Canned	94	0.6
Total poultry	6,556	13.0
Fish and Seafood		
Fresh	1,712	3.4
Frozen	511	1.0
Canned	1,610	3.2
Total Fish and Seafood	3,833	7.6
Total Meat, Poultry and Seafood	50,385	100.0

Source: Census of Manufactures (1977).

Of this amount, approximately 4.6 billion lb consisted of cured meats not smoked or cooked, while smoked, dried, and cooked meats also amounted to nearly 4.6 billion lb, chiefly hams and bacon, as shown in Table 1.7. Sectioned and formed hams and dry cured hams also contributed to the latter total.

Although fresh and frozen meat production totaled about 41 billion lb in 1981, part of the total included restructured steaks and mechanically processed meat. Some of the discrepancies in the totals are probably the result of a product being included in more than one category. Convenience foods, in which meat is an important constituent, amounted to about 1.5 billion lb in 1981.

Cured Meats

Although a large proportion of all processed meats are cured, it is difficult to separate them on this basis. Most sausages are cured, yet approximately 22% are sold as fresh sausages. Over 25% of all meat, including cured sausages and pork products, are cured. Thus, curing is one of the most important operations in processed meat production. Details on meat curing are covered in Chapter 3.

Sausages

Table 1.8 presents the distribution of sausage products, various sliced items, and animal shortenings produced under federal inspection in 1981. Total fresh sausages comprised some 1,104 million lb, with fresh pork sausage accounting for nearly 75% of all fresh sausages.

Table 1.9 gives the amounts and percentages of different types of sausages that were produced under federal meat inspection in 1981. As already indicated, nearly 22% of the total were fresh sausages. Over 28% of all sausages produced were frankfurters and wieners, while bologna comprises slightly over 15%. Dried and semidried sausages accounted for about 7% of the total, while liver sausage and braunschweiger comprised only slightly over 2% of the total.

Hams and Canned Hams

Table 1.7 presents information showing that approximately 1,856 million lb of cured hams were produced in the United States under federal inspection in 1981. They are classified as (1) bone-in hams, (2) semi-boneless hams, (3) boneless hams, (4) canned hams, (5) sectioned and formed hams, and (6) dry-cured hams.

Table 1.10 lists the data for domestic ham production and imports for 1981. Since 1970, boneless ham production has increased from 315.8

TABLE 1.7. Processed and Fresh/Frozen Meat Products Produced under Federal Inspection in 1981 Not Including Sausages

Item	Production (1000 lb)
Cured Meats—Not smoked or cooked	
Beef briskets—Cured	153,444
Other cured beef	126,453
Pork—Cured	4,275,862
Other—Cured meats	42,608
Total Cured Meats—Not smoked or cooked	4,598,367
Smoked, Dried or Cooked Meats	
Hams	
Bone-in hams	117,873
Bone-in hams—Water added	374,089
Semiboneless hams	13,191
Semiboneless hams—Water added	104,082
Boneless hams	110,514
Boneless hams—Water added	590,347
Sectioned and formed hams	93,051
Sectioned and formed hams—Water added	371,366
Dry cured hams	81,481
Total hams	1,855,995
Other pork—Regular	189,901
Other pork—Water added	268,035
Total other pork	457,936
Bacon—All	1,703,812
Total pork	4,017,743
Beef—Cooked	281,420
Beef—Dried	25,557
Other meats	269,075
Total—Smoked, dried and cooked meats	4,593,795
Total—Cured, smoked, dried and cooked products	9,192,162
Fresh/Frozen Meat Products	
Beef—Cuts	10,193,038
Beef—Boning	6,275,215
Pork—Cuts	12,394,123
Pork—Boning	4,076,184
Other—Cuts	529,584
Other—Boning	403,559
Mechanically processed	
Beef	4,686
Pork	51
Other	734
Steaks, chops and roasts	2,504,252
Steaks, chops (chopped and formed)	293,737
Meat Patties	547,010
Hamburger/ground beef	3,050,167
Other—Fresh/frozen	946,991
Total—Fresh/frozen	41,219,331

(*continued*)

TABLE 1.7. (*Cont.*)

Item	Production (1000 lb)
Convenience Foods (meat used)	
Pizza—Meat	464,565
Pies—Meat	164,751
Dinners—Meat	239,423
Entrees—Meat	316,842
Other	262,339
Total Convenience Foods	1,447,820

Source: American Meat Institute (1982A).

million lb to 1,165.3 million lb. This figure includes sectioned and formed hams, production of which amounted to 380.7 million lb, or about 33% of all boneless hams. Canned ham consumption, which includes both domestically produced and imported canned hams, has declined from about 34% to approximately 19% of the total. Changes in the proportion of other products produced are not apparent on examination of the data.

The data not only indicate an increased consumer demand for a boneless hams, but also reflect an increase in production of sectioned and formed hams. There has been steady growth in production of this class of hams in spite of the fact that total ham production has changed but little during the past few years. Production of dry cured hams increased from 67.5 million lb in 1977 to 81.5 million lb in 1981. It is difficult to tell whether this represents a trend, but it does indicate a steady demand for dry cured hams, which are accounted for mainly by country cured hams. These shelf-stable products are largely produced in the southeastern states, especially in Virginia, Georgia, North and South Carolina and Kentucky.

Canned Meats

Table 1.11 presents production data on canned meat products produced under Federal inspection in 1981. There are a great many of these canned meat products, with the amount of meat varying with the type of product. The more popular items include pasta products, luncheon meats, chili con carne, canned hams, meat stews, and Vienna sausages. Total canned meat production under Federal inspection amounted to 2,213.4 million lb. Thus, canned meat production utilizes about 4% of total meat production.

Canning of meat requires special equipment and careful quality control, since most meat products are low acid foods and must receive an

TABLE 1.8. Sausage and Sliced Products and Animal Shortening Produced under Federal Inspection in 1981

Item	Production (1000 lb)
Fresh sausages	
Fresh beef sausage	15,190
Fresh pork sausage	818,984
Fresh sausages—Other	256,826
Fresh cured, uncooked sausage	13,022
Total Fresh Sausage	1,104,022
Dried and Semi-dried Sausages	
Dried Sausages	248,897
Semi-dried sausages	95,246
Total Dried and Semi-dried sausages	344,143
Frankfurters and wieners	
Regular frankfurters—Retail	930,221
Regular frankfurters—Bulk	235,923
Frankfurters with extenders—Retail	60,724
Frankfurters with extenders—Bulk	70,808
Frankfurters with variety meats—Retail	35,238
Frankfurters with variety meats—Bulk	6,129
Frankfurters with extenders and variety meats—Retail	57,301
Frankfurters with extenders and variety meats—Bulk	22,287
Total Frankfurters and Weiners	1,418,631
Bologna	
Regular bologna	567,294
Bologna with extenders	42,787
Bologna with variety meats	92,524
Bologna with extenders and variety meats	58,496
Total Bologna	761,101
Miscellaneous sausages	
Liver sausages	118,324
Meat-loaves—Cured	102,896
Other cooked items	806,619
Total liver sausage, loaves and others	1,027,839
Nonspecific meat loaves	166,600
Other formulated products	214,045
Total Sausage	5,036,381
Sliced products	
Bacon—Retail	1,086,777
Bacon—Bulk	520,586
Total Bacon	1,607,363
Ham—Sliced	337,555
Sausage—Under 12 oz	277,778
Sausage—12 oz or over	657,144
Other sliced products	364,535
Total Sliced Products	3,244,375

(*continued*)

TABLE 1.8. (*Cont.*)

Item	Production (1000 lb)
Lard and Mixed Animal Shortenings	
Lard—Rendered	1,068,879
Lard—Refined	666,597
Tallow—Edible	1,468,228
Mixed animal shortenings	1,204,739
Total Lard, Tallow and Animal Shortening	4,408,443

Source: American Meat Institute (1982B).

adequate heat treatment to destroy *Clostridium botulinum*. More details on production of canned meats are given in Chapter 13.

Other Products

Convenience meat items, such as pizzas, meat pies, and meat entrees utilize about 2% of the total meat production. Demand for these items has greatly increased in recent years, and it seems likely there will be continued demand for these and other convenience meat products.

Many meat processors produce pet foods, but these products represent a specialized type of production and are not discussed herein.

Natural sausage casings are also made by some processors, and comprise 0.5% of the total value of all processed products. This operation is confined to large livestock slaughterers where considerable quantities of raw materials are available. Although these plants usually utilize a portion of the casings, they generally produce more than they use, and serve as suppliers for other sausage manufacturers.

TABLE 1.9. Amounts and Percentages of Different Types of Sausages Produced under Federal Inspection in 1981

Item	Amount Produced (1000 lb)	% of Total
Fresh sausages	1,104,022	21.9
Frankfurters	1,418,631	28.2
Bologna	761,101	15.1
Liver sausage and braunschweiger	118,324	2.3
Meat loaves—All	269,496	5.4
Dried and semidried sausages	344,143	6.8
Other sausage items	1,020,664	20.3
Total	5,036,381	100.0

Source: American Meat Institute (1982B).

TABLE 1.10. Ham Production and Imports in United States in 1981

Item	Amounts (million lb)	% of Total
Bone-in hams—Domestic production	492.0	20.8
Semiboneless hams—Domestic production	177.3	7.5
Boneless hams[a]—Domestic production	1,165.3	49.4
Dry cured—Domestic production	81.5	3.4
Canned hams—Domestic production	246.8	10.4
Total hams—Domestic production	2,162.9	91.6
Canned hams[b]—Imported	198.0	8.4
Canned hams—total (domestic and imported)	444.8	18.8
Total—All hams	2,360.9	100.0

Source: Adapted from American Meat Institute (1982B).
[a] Includes sectioned and formed hams.
[b] Includes shoulders.

TABLE 1.11. Canned Meat Products Produced Under Federal Inspection in 1981[a]

Item	1000 lb
Canned hams—Total	246,844
Luncheon meat—Canned all	259,798
Chili con carne	312,262
Meat stew	125,915
Hash products	72,832
Pasta products with meat	379,786
Pork picnics and loins	15,132
Vienna sausage	96,736
Frankfurters and wieners	1,420
Miscellaneous sausage products	27,045
Deviled ham	12,291
Potted products and spreads	38,291
Tamales	21,992
Sliced dried beef	2,878
Chopped beef/hamburger	12,126
Vinegar pickled products	16,321
By-products—Not pickled	3,097
Corned beef	828
All other products—Containing 20% or more meat	133,303
All other products—Containing less than 20% meat	434,552
Total Canned Meats	2,213,450

Source: Adapted from American Meat Institute (1982B).

TRENDS IN PRODUCTION

Increased demand for convenience foods has resulted in expansion of the processed-meat industry. This has been accelerated by the relatively large number of women employed outside the home and the consequent lack of time available for preparation of meals. Since meat has always required the longest period for preparation, it has benefited most from development of convenience items. This is best illustrated by the growth of heat-and-eat meals, such as TV dinners, where meat as the entree is the major contributor to the meal. Luncheon meats, such as frankfurters, bologna, and meat loaves, have also been major beneficiaries of the increased use of convenience foods.

It seems that the trend toward complete processing for consumer convenience and development of new products will continue. It is likely that the emphasis on convenience meat products will continue and that more processing and cooking will be demanded by consumers, resulting in more prepared and precooked items. The ingenuity of meat processors in anticipating and even in creating such demands may well determine the future of the processed-meat industry.

FUTURE OF MEAT PROCESSING

Speculation as to what the future holds is always dangerous; however, it is reasonably safe to prognosticate that the meat-processing industry will undergo changes during the next few years. Past developments and trends offer some clues to future changes. Government regulations on food safety and inspection offer some insight. Such measures promise to lead to more carefully controlled sanitation and quality control practices, which might be self-policed by processors. If they accept the challenge, processors must set up specific quality control standards. This means that they must develop quality control groups with the necessary personnel and laboratories for enforcement of standards. Thus, processors will need to be better informed, and to have a capable quality control department with direct responsibility to management.

Development of quality control procedures will necessarily increase costs and indirectly result in a need for greater efficiency. This might result in efforts to consolidate smaller companies and force small independent operators out of business or into a rapid expansion. Consolidation and diversification have already influenced the meat business and promise to continue in the future. Emphasis will be on growth and expansion as long as efficiency can be improved. It seems likely that small operators will have to emphasize quality production. Quality can be a basis for competing effectively, since small operators have been successful in the past, either because they were exempt from government regulations or because they produced high-quality products. With strict enforcement of meat inspection regulations, exemptions cannot be expected, and it seems that profitable operations will require manufacturing and marketing of quality products. The trend has been toward concentration in the meat-packing industry, and this is likely to continue.

The diversity of operations in plants may also change. The trends point toward an increase in the amount of processing within plants. Expansion of convenience products appears inevitable, with more trimming, shaping, cooking, and packaging represented in the finished products. More production of complete heat-and-serve products is probable.

Another innovation still in early developmental stages is production of mixed foods such as processed meats containing proteins from other sources, such as soy beans and sunflowers. These might be tailored to satisfy nutritional requirements, with a reduction in fat or a change in the content of unsaturated fatty acids. The rate at which this development occurs depends on the availability and costs of raw products of both animal and plant origin. Another aspect of this development could be the availability of artificial meat flavors and emphasis upon nutritional adequacy and balanced diets.

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2

Composition and Nutritive Value of Raw Materials and Processed Meats

Although meat is recognized as a highly nutritious food—being an excellent source of high-quality protein, rich in most B-complex vitamins, and a good source of certain minerals, especially iron—its composition can greatly alter its nutritive value. Therefore, composition and nutritional value will be discussed together. Since information on processed meat is fragmentary and incomplete, emphasis will be placed on the raw products, including their composition and nutritional qualities. Thus, the present discussion will first cover the composition and nutritive value of fresh meat as a raw material. It will center on some of the functional properties of the various nutrients. Data will also be presented to show some of the available information on the nutritive value of various processed-meat items.

EMPHASIS ON NUTRITION

The nutritive value of all foods, including meat and meat products, is being seriously considered in view of consumer interest and demand. Nutritional labeling is now required for most manufactured meat products. The major meat packers and processors are providing information on the nutritional value of most products. Such information is not required for fresh meat in view of its variability and the difficulty of controlling composition. The Food and Drug Administration does not require absolute compliance with label declarations but allows some degree of flexibility in accordance with estimates of variability. Labeling has, however, resulted in less product variability. Development of more manufactured meat products will, no doubt, increase the degree of compliance. This is important since the consumer can no longer recognize the traditional food groups and utilize such information in properly balancing his own diet. Since many processed-meat items are also manufactured foods, they are required to have labels specifying their nutritive content.

A. M. Pearson et al., *Processed Meats*

COMPOSITION AND NUTRITIVE VALUE OF MEAT

The composition of meat cannot be described simply in terms of the different components and their percentages, since meat includes the entire carcass along with the muscles, fatty tissues, bones, tendons, edible organs, and glands. This obviously gives a wide range of components, and thus, of composition and nutritive value. Consequently, when speaking about meat, it is necessary to specify the tissue or cuts and whether or not it includes the bone and tendon, as well as the amount of external fat covering and the quantity of marbling. This is clearly shown in Fig. 2.1, where the relative changes in fatty tissues, muscle, bone, and tendon are plotted relative to the percentage fat in the carcass. The percentage of separable lean varies widely and is inversely related to the fat content. It is also interesting to note that the percentage of bone and tendon declines directly with the amount of muscle.

Variation in composition results in differences in nutritive value. This is further complicated by the fact that variation in composition also occurs from species to species. It is impossible to cover the different causes of variation adequately, so the reader is referred to the bibliography of this chapter for more complete details.

Composition of Meat

Water and Fat. Grossly speaking, meat is composed of water, fat, protein, mineral (ash), and a small proportion of carbohydrate. Table 2.1 presents data for these components in some carcasses and cuts that

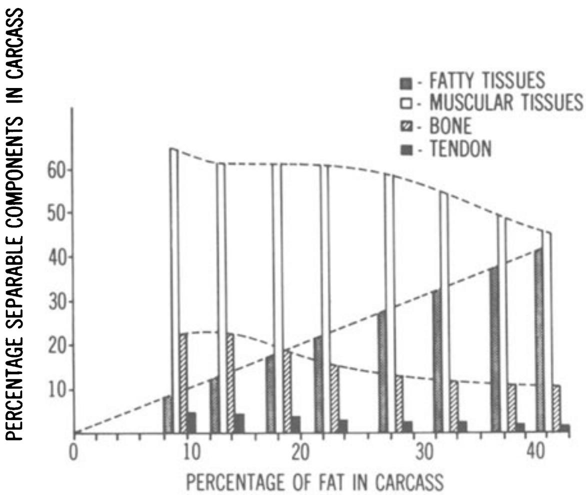


FIG. 2.1. Changes in the proportions of muscle, fatty tissues, bone, and tendon as the carcass changes in fatness. From Callow (1948).

TABLE 2.1. Some Selected Values for the Calorie, Water, Protein, Fat, and Ash Content of Various Grades and Cuts of Meat on a Raw and Cooked Basis per 100 Grams of Edible Portion

Product and grade	Calories	Water	Protein	Fat	Ash
Beef Carcass—Total edible, including Kidney and Kidney Fat					
Good grade (66% lean, 34% fat), raw	323	54.7	16.5	28.0	0.8
Standard grade (73% lean, 27% fat), raw	266	60.1	18.0	21.0	0.9
Commercial grade (64% lean, 36% fat), raw	347	52.4	15.8	31.0	0.8
Utility grade (76% lean, 24% fat), raw	242	62.5	18.6	18.0	0.9
Beef round—Choice grade—separable lean, raw	135	72.7	21.6	4.7	1.0
Beef round—Choice grade—separable lean, cooked	189	61.2	31.3	6.1	1.4
Beef chuck—Choice grade—separable lean, raw	158	70.3	21.3	7.4	1.0
Beef chuck—Choice grade—separable lean, cooked	214	59.7	30.0	9.5	0.8
Lamb, composite of cuts (leg, loin, rib, and shoulder) trimmed—Good grade (79% lean, 21% fat) raw	247	62.5	16.8	19.4	1.3
Lamb leg—Good grade—separable lean, raw	127	73.8	19.9	4.7	1.6
Lamb leg—Good grade—separable lean, cooked	183	62.4	28.7	6.7	2.1
Lamb shoulder—Good grade—separable lean, raw	145	72.8	18.5	7.3	1.4
Lamb Shoulder—Good grade—separable lean, cooked	201	61.8	26.8	9.6	1.9
Pork, carcass—thin (53% lean, 47% fat), raw	472	41.1	11.2	47.0	0.6
Pork, carcass—thin separable lean, raw	156	70.7	18.3	8.6	2.4
Pork, shoulder—thin (75% lean, 25% fat), raw	368	51.7	13.6	34.4	0.7
Pork, ham trimmed thin (77% lean, 23% fat), raw	281	59.2	16.7	23.2	0.8
Pork, ham trimmed thin (77% lean, 23% fat), cooked	346	47.8	24.2	26.9	1.0
Pork ham, thin separable lean, raw	147	72.0	20.4	6.6	1.1
Pork ham, thin separable lean, cooked	210	59.3	30.2	9.0	1.5
Veal, carcass—thin (86% lean, 14% fat), raw	173	70.0	19.4	10.0	1.0
Veal, chuck—thin (90% lean, 10% fat), raw	139	73.0	19.9	6.0	1.1
Veal, round and rump—thin (91% lean, 9% fat), raw	139	73.0	19.9	6.0	1.1

Source: USDA Handbook No. 8

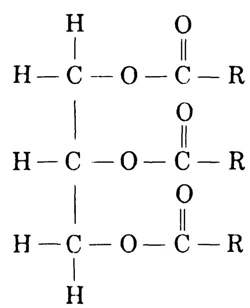
are commonly used for the manufacture of processed-meat items. As can be seen from the data, water is the most variable of these components, but is closely and inversely related to the fat content and to a lesser extent to the ash and carbohydrate content. In general terms, if the fat content is held relatively constant, the percentage of water declines until the animal body reaches chemical maturity, regardless of the species. However, as animals mature, they also usually increase in fatness, which causes an even greater decline in the percentage of water. This is illustrated by the fact that a baby pig at birth contains approximately 77–80% water, 12–13% protein, and 3–4% ash, whereas 24 pigs weighing 181–220 lb averaged 49% water, 33% fat, 13.5%

protein, and 2.7% ash. These figures are for the entire body, including bone. On a carcass basis, the same pigs averaged approximately 46% water, 38% fat, 13% protein, and 2.7% ash. This shows that the fat content of the carcass is higher and the water content is lower than that of the intact animal. However, the bone content as reflected by percentage ash remained essentially unchanged.

These data bear out the inverse relationship between fat and water and the influence of fatness on composition. This is not only true for chemically determined fat but also for fatty tissues, which have a relatively low water content. Values as low as 4.5% water and as high as 64.5% water have been reported for beef fat from the kidney knob and over the rib, respectively. These values are obviously extremes, normal values being much less. Variations in the water content of composite fatty tissues from pork carcasses fall within a range of 8–15%, which still represents approximately 100% variability. Thus, not only the amount of fatty tissue, but also its composition is required to estimate accurately its influence on the composition and nutritive value of any processed meat product in which fat is incorporated.

The fat content of the carcass, as already indicated, is highly variable and inversely related to the moisture level. Figure 2.1 shows that fatty tissues vary from a few percent to over 40% in the beef carcass. Considerably higher values have been reported in the literature, some beef carcasses containing as much as 50% separable fat and some sheep (old ewes) over 60%. Similarly, high proportions of fat have also been found in pig carcasses.

Animal fats are composed chiefly of neutral fats and phospholipids. The neutral fats are principally glycerol esters of straight-chain carboxylic acids or triglycerides. The triglyceride may be simple or mixed, depending on whether the three fatty acids esterified to the glycerol molecule are the same or different. This is shown by the following structural formula in which all three R-groups (representing the fatty acid radical) may be the same (simple) or different (mixed):



Phospholipids are found in animal fats in small percentages; they play a key role as structural and functional components of cells and membranes. Phospholipids normally occur in meat as phosphoglycerides. They normally comprise about 0.5–1.0% of lean muscle. As the total lipid in a muscle decreases from 5 to 1%, the percentage of phospholipid to total lipid increases from less than 10% to nearly 70%. Since phospholipids are more readily oxidized than triglycerides, they play an important part in development of off-flavors and undesirable odors in meat products.

The major contribution of fat to the diet is energy or calories. This is true because fat has 2.25 times as much energy as an equal quantity of carbohydrate or protein. However, energy is not normally the limiting factor in most American diets; rather, too many calories is the more likely problem. On the other hand, limiting the intake of fat is a common method of weight control. This creates a demand for lean meat products with a low fat content, such as boiled ham, Canadian-style bacon, Lebanon bologna, and similar products.

Fat also supplies the essential fatty acids, which must be present in the diet to meet the needs of the body. Three fatty acids are considered essential for man—linolenic, linoleic, and arachidonic. However, if linoleic acid is present in excess of dietary needs, it can be converted to arachidonic and thereby meet the requirements for the latter. Nutritional deficiencies of the essential fatty acids are seldom encountered in man; thus typical mixed diets appear to supply adequate quantities. Pork and organ meats are good sources of linoleic and linolenic acids, but they also occur in lesser concentrations in other meats. Table 2.2 presents data showing essential and nonessential fatty acid distribution in beef, pork, and lamb.

The controversy concerning animal fat in the diet and its relationship to heart disease and related circulatory disorders is worthy of mention, although the story is far from clear. Cholesterol came into prominence because it was found in high levels in the plaques obstructing the arteries of patients with heart disease. Subsequently, it was reported that high dietary levels of unsaturated fatty acids in the form of vegetable oils were effective in reducing circulating cholesterol in the blood stream of high-risk heart patients. Several recent studies have shown that there is no clear-cut relationship between the inci-

TABLE 2.2. Typical Fatty Acid Distribution in Beef, Pork, and Lamb Fat Given as Percentage of the Total

Fatty Acid	Beef	Pork	Lamb
Palmitic	29	28	25
Stearic	20	13	25
Palmitoleic	2	3	—
Oleic	42	46	39
Linoleic	2	10	4
Linolenic	0.5	0.7	0.5
Arachidonic	0.1	2	1.5

dence of heart disease and the level of animal fats in the diet, thus tending to discount the role of cholesterol in heart disease. This is supported by the fact that cholesterol is formed in the body, even when completely absent from the diet. A great many other factors have also been implicated as contributors to coronary disease, including heredity, obesity, smoking, sugar intake, and lack of exercise. The causes of heart disease and the role of cholesterol and animal fats, if any, are difficult to assess. Nevertheless, awareness of the possible relationship is essential. If the relationship should be proved real, steps to correct the situation by reducing fat levels would be essential.

To summarize briefly, cholesterol is a minor but important component of animal tissues. It occurs either free (unesterified) or combined with a fatty acid (esterified). Lean beef, pork, and lamb contain 70–75 mg cholesterol per 100 g, 90% being in the free form. Fatty tissues contain about the same percentage, so that reduction of fat intake will effectively lower dietary cholesterol levels. Veal contains slightly more cholesterol than beef, pork, or lamb, whereas, liver and brain contain 300 and 2,000 mg per 100 g, respectively.

Recently, the National Academy of Sciences has issued the report entitled "Diet, Nutrition, and Cancer," which suggested dietary fat may be involved in cancer in humans. The same report has also suggested that "meats preserved by salt and smoking" may also contribute to an increased incidence of cancer. On this basis, the report recommended that consumers should decrease their intake of calories from fat to 30% from its present level of about 40%. It further recommended a reduction in consumption of salt cured and smoked foods, which has been interpreted to include all cured meats and sausages. Many scientists feel that the changes in diet recommended by the Committee are not justified, and have suggested that its adoption by the public may have adverse instead of positive effects on human health. Regardless of which view is correct, its adoption could markedly decrease consumption of processed meats.

Minerals or Ash. Ash content accurately reflects the mineral content but does not differentiate between minerals. Aside from bone or minerals added as curing salts or for seasoning, the mineral content of muscle is relatively constant. Because of the relatively low content of minerals in fatty tissues, the fat level also indirectly influences the mineral or ash content of meat and meat products.

As already indicated, bone, which is reflected in the amount of ash, is a major component of the intact carcass. High ash content alone, however, cannot be taken as indicative of high bone content, since the addition of curing salts increases the ash content, as already mentioned. Dry sausages may also have a high ash content due to concentration of the natural minerals, as well as of the curing salts, during the drying process. Since curing salts are commonly used in most dried sausages or meat products, the added salts are also concentrated, and thus contribute to the total mineral content. The effects of curing salts and drying on the ash content are shown by the data for sausages and cured meats as summarized in Table 2.3.

Separable bone in the beef carcass varies from a low of 8 or 9% to a high of 23 or 24%. This is shown in Fig. 2.1, which also illustrates the inverse relationship of bone to fatness and a direct relation to leanness. Since most processed meat is boneless, one can estimate the yields of muscle that can be expected from beef carcasses of different fat contents.

Studies of the mineral content of meat have been largely confined to calcium, phosphorus, sodium, potassium, and iron. In addition to these five minerals, recent studies have reported on the content of magnesium, copper, and zinc in baby foods and several other processed items. Meat is a good source of dietary phosphorus and iron, but is low in calcium. Recent data from Swift's Research Laboratory showing the nutritional value of several processed-meat products and baby foods containing meat provides up-to-date information on the mineral and vitamin content of these foods (Table 2.4).

Recent research has demonstrated that meat is not only a rich source of dietary iron, but that it enhances iron absorption from other sources. The iron content of meat products is particularly important in providing a readily available source of iron in the diet of nonpregnant premenopausal women, who have a recommended daily allowance (RDA) of 18 mg per day.

It is interesting to compare the analysis in Table 2.4 with that found in Table 2.5 since both give values for baby foods containing meat. However, Table 2.4 gives data for analyses in 1972, whereas, Table 2.5 was published in 1963. Note that sodium levels are considerably lower in the present analysis (Table 2.4). Salt was added to these products until recent years, when it was voluntarily removed by the industry; thus the present levels are considerably reduced. Although there are other minor differences in the mineral content of the same products shown in Tables 2.4 and 2.5, they are of less importance. Note, however, that Table 2.4 (the 1972 data) also includes information on magnesium, zinc, and copper content, which reflects interest in more complete nutritional information. Table 2.4 also presents data showing the percentage of the recommended daily allowance supplied by a serving of each of the items for which recommended daily allowances have been established.

An observed relationship between sodium intake and hypertension for some 20% of the population has resulted in efforts to reduce voluntarily sodium levels in processed foods, including meats. Labeling with sodium levels is now being required in the nutritional information on the labels. Processors who are not using nutritional labeling are being permitted to put information on sodium levels of their products without complete nutritional information. Reduction of salt levels in pro-

TABLE 2.3. Calorie, Water, Protein, Fat, Carbohydrate, and Ash Content of Some Sausages and Canned Meat Items

Product Description	Calories	Water	Protein	Fat	Carbo-hydrate	Ash
Blood sausage or blood pudding	394	46.0	14.1	36.9	0.3	2.3
Bockwurst	264	61.9	11.3	23.7	0.6	2.5
Bologna						
all samples	304	56.2	12.1	27.5	1.1	3.1
all meat	277	57.4	13.3	22.8	3.7	2.8
with nonfat dry milk	—	57.1	13.4	—	—	—
Braunschweiger	319	52.6	14.8	27.4	2.3	2.9
Brown-and-Serve sausage,						
before browning	393	45.3	13.5	36.0	2.7	2.5
after browning	422	39.9	16.5	37.8	2.8	3.0
Capicola	499	26.2	20.2	45.8	0	7.9
Cervelat, dry	451	29.4	24.6	37.6	1.7	6.7
Country style sausage (pork sausage, smoked)	345	49.9	15.1	31.1	0	3.9
Deviled ham, canned	351	50.5	13.9	32.3	0	3.3
Frankfurters						
all samples, unheated	309	55.6	12.5	27.6	1.8	2.5
all meat, unheated	296	56.5	13.1	25.5	2.5	2.4
with nonfat dry milk, unheated	300	54.2	13.1	25.5	3.4	3.7
heated or cooked	304	57.3	12.4	27.2	1.6	1.5
canned	221	66.0	13.4	18.1	0.2	2.3
Headcheese	268	58.8	15.5	22.0	1.0	2.7
Knockwurst	278	57.6	14.1	23.2	2.2	2.9
Liverwurst						
fresh	307	53.9	16.2	25.6	1.8	2.5
smoked	319	52.6	14.8	27.4	2.3	2.9
Luncheon meat						
boiled ham	234	59.1	19.1	17.1	0	4.9
chopped, spiced pork	294	54.9	15.0	24.9	1.3	3.9
Meat loaf	200	64.1	15.9	13.2	3.3	3.5
Meat potted (beef, chicken, or turkey)	248	60.7	17.5	19.2	0	2.8
Minced ham	228	61.7	13.7	16.9	4.4	3.3
Mortadella	315	48.9	20.4	25.0	0.6	5.1
Polish style sausage	304	53.7	15.7	25.8	1.2	3.6
Pork sausage						
link or bulk, raw	498	38.1	9.4	50.8	Trace	1.7
link or bulk, cooked	476	34.8	18.1	44.2	Trace	2.9
Salami						
dry	450	29.8	23.8	38.1	1.2	7.1
cooked	311	51.0	17.5	25.6	1.4	4.5
Scrapple	215	61.3	8.8	13.6	14.6	1.7
Souse	181	70.3	13.0	13.4	1.2	2.1
Thuringer	307	48.5	18.6	24.5	1.6	6.8
Vienna Sausage, canned	240	63.0	14.0	19.8	0.3	2.9
Turkey, meat only, canned	202	64.9	20.9	12.5	0	1.7

Source: USDA Handbook No. 8

TABLE 2.4. Nutritional Analysis of Some Meat Products[a]

Nutrient—Amount	Brown N'Serve Bacon and Sausage Heated	Brown N'Serve Sausage Heated	Mild Cured Nonsmoked Brown N' Serve Sausage Heated	Strained canned baby food					Junior canned baby food				Ham Fully Cooked Canned
				Veal with Veg-etables	Ham with Veg-etables	Turkey with Veg-etables	Beef with Veg-etables	Chicken with Veg-etables	Turkey with Veg-etables	Beef with Veg-etables	Veal with Veg-etables	Chicken with Veg-etables	
Moisture (g/100 g)	47.2	45.0	41.7	84.7	79.9	84.7	81.2	84.7	81.2	78.4	78.6	81.7	62.2
Energy (kcal/100 g)	361	388	431	68	109	67	99	68	83	112	109	83	223
kcal or % RDA/serving	216	232	258	10.0	15.0	9.0	14.0	10.0	12.0	16.0	15.0	12.0	221
Protein (g/100 g)	16.5	14.6	13.0	6.3	6.3	5.4	5.7	5.3	5.8	6.6	6.6	5.4	18.1
% RDA/serving	15.0	13.0	12.0	50.0	50.0	43.0	45.0	42.0	46.0	52.0	52.0	43.0	28.0
Fat (g/100 g)	31.4	35.0	41.0	1.7	6.0	1.5	5.2	1.7	2.0	5.5	5.2	2.4	15.8
g/serving	18.8	21.0	24.6	2.1	7.6	1.9	6.6	2.1	2.5	7.0	6.6	3.0	15.6
Carbohydrate (g/100 g)	2.0	2.6	1.5	6.7	7.2	7.8	7.3	7.7	10.3	8.8	8.8	9.8	0.9
g/serving	1.2	1.5	0.9	8.5	9.1	9.9	9.3	9.8	13.1	11.2	11.2	12.5	0.8
Ash (g/100 g)	2.9	2.8	2.8	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.8	0.7	3.0
g/serving	1.7	1.6	1.6	0.7	0.7	0.7	0.7	0.7	0.8	0.8	1.0	0.8	2.9
Calcium (mg/100 g)	Tr	Tr	Tr	Tr	Tr	64	Tr	19	80	Tr	Tr	24	Tr
% RDA	Tr	Tr	Tr	Tr	Tr	14	Tr	4	17	Tr	Tr	5.0	Tr
Phosphorus (mg/100 g)	130	110	100	55	63	63	49	57	83	74	76	67	190
% RDA	8.0	7.0	6.0	14.0	16.0	16.0	13.0	15.0	21.0	19.0	19.0	17.0	19.0
Iron (mg/100 g)	1.2	1.2	0.8	1.4	0.3	0.7	1.2	0.4	0.8	0.8	1.8	0.7	1.0
% RDA	4.0	4.0	3.0	12.0	3.0	6.0	10.0	3.0	7.0	7.0	15.0	6.0	6.0
Sodium (mg/100 g)	870	850	860	130	140	150	150	160	140	160	170	150	850
mg/serving	522	510	516	165	178	191	191	204	178	204	216	191	844
Potassium (mg/100 g)	210	180	160	110	100	64	88	54	100	170	220	110	240
mg/serving	126	108	96	140	127	81	112	68	127	216	280	140	238

Magnesium													
(mg/100 g)	15	12	10	8	9	6	8	6	15	12	15	8	17
% RDA	2.0	2.0	2.0	15.0	16.0	11.0	15.0	11.0	27.0	22.0	27.0	15.0	4.0
Zinc (mg/100 g)	2.2	1.8	1.7	1.9	1.2	1.7	1.3	0.07	1.7	1.5	2.3	0.7	1.9
mg or % RDA/serving	9.0	7.0	7.0	2.4	1.5	2.1	1.6	0.8	2.1	1.9	2.9	0.8	13.0
Copper (mg/100 g)	0.07	0.04	0.03	0.18	0.07	0.09	0.07	0.02	0.09	0.14	0.10	0.07	0.06
mg or % RDA/serving	2.0	1.0	1.0	0.22	0.08	0.11	0.08	0.02	0.11	0.17	0.12	0.08	3.0
Vit. A (IU/100 g)	NA	NA	NA	624	559	841	888	442	3105	1024	3745	2610	NA
% RDA	NA	NA	NA	53.0	48.0	72.0	76.0	38.0	264.0	87.0	319.0	222.0	NA
Thiamine (mg/100 g)	0.44	0.34	0.35	0.09	0.08	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.92
% RDA	18.0	14.0	14.0	23.0	20.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	61.0
Riboflavin													
(mg/100 g)	0.17	0.15	0.14	0.06	0.06	0.04	0.07	0.04	0.05	0.07	0.07	0.06	0.20
% RDA	6.0	5.0	5.0	13.0	13.0	9.0	15.0	9.0	11.0	15.0	15.0	13.0	12.0
Niacin (mg/100 g)	3.66	3.47	3.41	1.29	0.95	0.40	1.16	0.62	0.53	1.36	1.53	0.81	3.17
% RDA	11.0	10.0	10.0	21.0	15.0	6.0	19.0	10.0	8.0	22.0	24.0	13.0	16.0
Pantothenic Acid													
(mg/100 g)	0.446	0.300	0.530	0.127	0.167	0.138	0.087	0.212	0.077	0.190	0.199	0.115	0.140
mg/serving	0.279	0.180	0.318	0.162	0.213	0.176	0.111	0.270	0.098	0.242	0.253	0.146	1.0
Vit. B_6 (mg/100 g)	0.045	0.042	0.038	0.019	0.025	0.120	0.019	0.019	0.016	0.23	0.021	0.023	0.198
% RDA	1.0	1.0	1.0	6.0	8.0	38.0	6.0	6.0	5.0	7.0	7.0	7.0	10.0
Vit. B_{12} (μg/100 g)	0.47	0.367	0.70	0.30	0.28	0.16	0.29	0.17	0.20	0.20	0.35	0.12	0.21
% RDA	5.0	4.0	7.0	19.0	18.0	10.0	19.0	11.0	13.0	13.0	22.0	8.0	3.0
Folacin (mg/100 g)	0.002	0.002	0.001	0.001	0.000	0.001	0.003	0.002	0.001	0.001	0.002	0.001	0.004
% RDA	Tr	Tr	Tr	1.0	Tr	2.0	4.0	3.0	2.0	2.0	3.0	2.0	1.0
Ascorbic Acid													
(mg/100 g)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
% RDA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Source: Swift and Company's Nutritional Data Bank
[a] NA—not available; Tr—Trace

TABLE 2.5. Mineral and Vitamin Content of Some Canned Baby Foods Containing Meat, Expressed as Amount per 100 g Edible Portion[a]

Product Description	Calcium (mg)	Phosphorus (mg)	Iron (mg)	Sodium (mg)	Potassium (mg)	Vit. A (I.U.)	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)	Ascorbic Acid (mg)
Beef noodle dinner	12	29	0.5	269	159	620	0.02	0.05	0.5	2
Cereal, egg yolk and bacon	29	60	0.8	301	36	520	0.05	0.06	0.4	—
Macaroni, tomatoes, meat and cereal	21	35	0.5	381	77	500	0.14	0.12	1.0	1
Split peas, vegetables and ham or bacon	29	79	0.7	295	112	600	0.08	0.05	0.5	1
Vegetables and bacon with cereal	17	28	0.6	282	130	2,200	0.07	0.05	0.6	1
Vegetables and beef with cereal	17	39	0.8	307	143	2,800	0.03	0.04	0.9	1
Vegetables and chicken with cereal	33	33	0.4	307	55	1,000	0.03	0.04	0.5	Trace
Vegetables and ham with cereal	25	42	0.3	360	90	1,000	0.08	0.05	0.5	3
Vegetables and lamb with cereal	23	37	0.7	269	148	2,700	0.03	0.05	0.7	1
Vegetables and liver with cereal	17	57	2.7	236	162	4,700	0.04	0.37	1.6	3
Vegetables and liver with bacon and cereal	11	42	2.6	284	131	4,600	0.03	0.33	1.3	2
Vegetables and turkey with cereal	22	26	0.3	307	46	400	0.01	0.03	0.4	1
Beef with vegetables	13	84	1.2	304	113	1,100	0.07	0.17	1.6	2
Chicken with vegetables	22	85	0.9	265	71	1,000	0.09	0.15	1.6	2
Turkey with vegetables	38	63	0.6	348	122	1,000	0.13	0.13	1.8	2
Veal with vegetables	11	71	0.8	323	95	800	0.08	0.15	2.0	2
Beef, Strained	8	127	2.0	228	183	—	0.01	0.16	3.5	0
Beef, Junior	8	163	2.5	283	242	—	0.02	0.20	4.3	0
Beef Heart	5	155	3.7	208	—	—	0.06	0.62	3.6	0
Chicken	—	129	1.9	263	96	—	0.02	0.16	3.5	0
Egg yolks with ham or bacon	71	185	2.8	313	82	1,900	0.10	0.23	0.5	—
Lamb, Strained	9	124	2.1	241	181	—	0.02	0.17	3.3	—
Lamb, Junior	13	156	2.7	294	228	—	0.02	0.21	4.1	—
Liver, Strained	6	182	5.6	253	202	24,000	0.05	2.00	7.6	10
Liver and bacon, strained	6	157	4.2	302	192	22,000	0.05	1.99	7.8	7
Pork, Strained	8	130	1.5	223	178	—	0.19	0.20	2.7	—
Pork, Junior	8	144	1.2	237	210	—	0.23	0.23	2.8	—
Veal, Strained	10	145	1.7	226	214	—	0.03	0.20	4.3	—
Veal, Junior	8	157	1.6	276	206	—	0.03	0.22	6.0	—

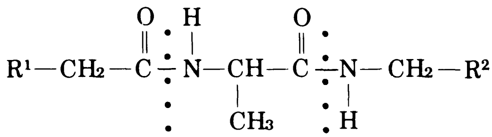
Source: USDA Handbook No. 8

[a] 0 indicates no detectable amounts; — indicates no reliable data: the amount is believed to be negligible

cessed meats will, no doubt, continue to be emphasized in view of its association with hypertension.

Protein. From the standpoint of nutrition, the nitrogenous components of meat are probably the most important. These compounds can be divided into protein and nonprotein nitrogen (NPN). Nonprotein nitrogen exists chiefly as free amino acids and amides. The principal amides include urea, hippuric acid, guanidine, creatine, and glutathione. The free amino acids may include any of those found in the tissues. The nonprotein nitrogen fraction comprises only a small proportion of the total nitrogen in meat, and for practical purposes is not normally separated in the analysis.

Proteins are polypeptides or combinations of amino acids linked together into chains by the reaction of amino and carboxyl groups of adjoining amino acids by means of peptide linkages, as shown in the following formula:



Each dotted vertical line is at the point of the peptide linkage of adjacent amino acids, while the symbols R^1 and R^2 represent further chains of amino acids linked together by means of peptide linkages to form complete proteins. Various amino acids are, of course, included in the proteins.

In common with fats and carbohydrates, proteins contain carbon, hydrogen, and oxygen. However, they also contain a large and fairly constant proportion of nitrogen, normally in a range of 15.5 to 18%. Meat proteins also frequently contain sulfur, and a few contain phosphorus and iron. The nitrogen content of meat proteins is about 16%, which means the protein content of meat is 6.25 times the nitrogen content.

Muscle or meat proteins can be divided into three different fractions on the basis of function and solubility: (1) sarcoplasmic or water-soluble, (2) myofibrillar or salt-soluble, and (3) connective tissue or insoluble fraction. Actually, the solubility classification is only a simple guide, to which there are a number of exceptions, yet this classification is sufficiently accurate for the present discussion.

Sarcoplasmic Proteins. The sarcoplasmic fraction consists of those proteins found in the sarcoplasm, or the fluid surrounding and bathing the myofibrils. Sarcoplasmic proteins are often referred to as water-soluble proteins, because they are commonly extracted with water or low ionic strength (0.06) salt solutions. This fraction contains the oxidative enzymes, including the cytochromes, the flavin nucleotides, the various heme pigments, and the mitochondrial oxidative enzymes. The sarcoplasmic fraction also contains the glycolytic enzymes, which control both aerobic and anaerobic glycolysis, thereby functioning in the conversion of glycogen to lactic acid and the aerobic oxidation of pyruvate. In addition, the sarcoplasmic classification also contains lysosomal enzymes and nucleoproteins, which function in hydrolytic degradation of waste material and regulate protein synthesis and deposition, respectively. It can be readily seen that the sarcoplasmic fraction covers a widely divergent group of proteins that control a widely differing group of tissue functions.

Sarcoplasmic proteins are effective emulsifiers of fat in model sausage systems, being equal or superior to the myofibrillar fraction. Emulsions formed by the sarcoplasmic fraction are not as stable as those formed by the myofibrillar proteins, but are more stable than emulsions in which the connective tissue fraction composes the protein matrix. Thus sarcoplasmic proteins make a contribution to sausage emulsions.

Myofibrillar Proteins. Myofibrillar proteins are also known as contractile proteins by virtue of the key role they play in muscle contraction and locomotion in the living animal. After death, these proteins function in the development of rigor mortis, which is essentially an irreversible reaction limited by the unavailability of substrate. The principal proteins in the myofibrillar fraction include myosin, actin, and the combination form of actomyosin, which results from contraction of muscle, or in the case of meat, during development of rigor mortis. In addition, the myofibrillar fraction includes tropomyosin, troponin, the actinins (α and β forms) and perhaps other minor regulatory proteins, which play major roles in muscle and meat, although present in lower percentages than actin and myosin.

The myofibrillar or so-called salt-soluble proteins are commonly extracted with potassium chloride, usually at an ionic strength of 0.3. The salt solubility of this fraction is normally taken advantage of in sausage manufacture by adding 2–3% salt before or during chopping or emulsification in order to extract and make a salt solution of the protein. The salt-soluble extract then coats the fat during formation of the emulsion. As already indicated, the myofibrillar protein–fat emulsion is not only efficient per unit of protein but is also very stable.

Connective Tissue Proteins. Connective tissue proteins function as a supporting framework for the living body, and thus serve in numerous and variable functions. This fraction includes two distinctly different proteins, collagen and elastin, and also probably another, reticulin, which is less well-defined than the former two.

Collagen is the principal component of the connective-tissue fraction. It is found widely distributed in the body and comprises 20–25% of the total protein. It is the principal protein in bone, tendon, and skin. It also comprises the protein matrix for deposition of depot fat, and supports and contains the individual muscle fibers, the bundles of fibers, and the muscles themselves. Collagen fibers are not dissolved by dilute acid or alkali solutions or by concentrated solutions of certain neutral salts and nonelectrolytes unless they have been previously denatured by heat or urea. The fibers are readily digested by pepsin and collagenase, but are resistant to trypsin and chymotrypsin digestion. Collagen is characterized by undergoing a sharply defined thermal shrinkage at a given temperature, which is characteristic of the species at a given age. Prolonged heat treatment above the thermal shrinkage temperature converts collagen to soluble gelatin. The latter property is responsible for fat accumulation in sausage emulsions prepared from collagen and will be discussed in greater detail later in this section.

Collagen is characterized by an unusual amino-acid composition. Glycine represents nearly one-third of the total amino acid residues, while hydroxyproline comprises about 10%, alanine approximately 11% of the total, and proline 12%. Hydroxylysine, which is characteristically confined to collagen in nature, makes up a small (less than 1%) but consistent percentage of collagen. Tyrosine, histidine, and the sulfur-containing amino acids are present in amounts less than 1%, which is unusually low. Thus, the polar residues compose about 18% and amides 5% of the total amino acid residues. Collagen is characterized by inter- and intramolecular cross-links, the extent of cross-linking increasing with the animal's age. Collagen from older animals has more cross-linking, and is consequently more difficult to extract.

Elastin belongs to a unique class of proteins, being extremely unreactive. It is a minor component of most tissues but is found in appreciable amounts in the ligaments of the vertebrae and in the walls of large arteries. It has a yellow appearance and fluoresces as bluish white fibers under ultraviolet light. Elastin has a low content of polar groups and stains poorly with acidic or basic dyes, but does stain with orcein and some other phenolic dyes. Elastin contains 1–2% hydroxyproline. The content of tryptophan, tyrosine, and the sulfur-containing amino acids is low, similar to collagen. It does not contain any measurable hydroxylysine, but does contain two characteristic amino acids, desmosine and isodesmosine. Like collagen, glycine comprises about one-third of the amino acid residues.

The third recognized protein component of connective tissues is reticulin. It is chemically very similar to collagen and many researchers believe it to be merely another form of collagen. Reticulin fibers are fine and wavy and show some branching. Reticulin shows distinctly different morphological and histological characteristics from collagen. However, on hydrolysis it yields gelatin. Reticulin fibers appear as black shining threads on staining with ammoniacal silver solutions, whereas mature collagen stains brown. In view of its transformation to gelatin on prolonged heating, reticulin probably behaves like collagen in sausage emulsions.

Collagen and, apparently, reticulin are extracted by the salt added to sausage, and coat the fat particles during emulsification. Their ability to emulsify fat is quite low in view of the instability of the finished emulsion. On heating the emulsion, collagen and reticulin are gelantinized and fat is released. This can be an important factor in the accumulation of fat during heat-processing of emulsion-type sausages. As elastin is relatively unreactive, it is not extracted and apparently has little effect upon sausage, but would likewise not contribute to the emulsifying capacity.

Unlike sarcoplasmic and myofibrillar proteins, which are high-quality proteins and contribute a good balance of essential amino acids, connective-tissue proteins are low in the sulfur-containing amino acids and tryptophan. Thus, connective-tissue proteins would require special dietary supplementation with trytophan and histidine to improve their nutritional value. Meat by-products that are high in bone or in hides are of relatively poor biological value. Fortunately, lean meat is largely composed of myofibrillar and sarcoplasmic proteins, and so is of excellent quality. The biological value of lean-meat proteins used for sausage emulsions and other meat products is excellent.

Carbohydrates

Immediately postmortem, muscle normally contains a small amount (about 1%) of glycogen, most of which disappears before completion of rigor. It serves an important function in controlling muscle pH, which is the net effect of the extent of glycolysis. Both the rate and amount of glycogen breakdown control the physical properties of meat, such as water-holding capacity, color, and tenderness. Rapid glycolysis, while the muscle temperature is still high, has been shown to be a causative factor in development of PSE (pale, soft, and exudative) muscle in the pig. Similarly, early freezing before completion of glycolysis has been found to cause excessive muscle shortening, thus contributing to toughness in meat. This has been well established in New Zealand, where excessive toughness in lamb has been encountered as a result of freezing immediately after slaughter. The closely related phenomenon of thaw rigor, which occurs on thawing of prerigor frozen meat and results in excessive drip losses upon thawing, can also be prevented by allowing meat to pass through rigor before freezing.

After completion of rigor mortis, the amount of glycogen is usually greatly reduced or in many cases completely absent. If the glycogen and creatine phosphate are all used up before the pH reaches the normal level of 5.3 to 5.6, the pH remains high. The resulting high-pH meat is commonly called "dark cutting" because of its dark appearance and low oxygen uptake. "Dark-cutting" meat has a high water-holding capacity. High-pH meat is not only objectionable from the standpoint of appearance and flavor, sometimes being "soapy" in taste, but also is subject to spoilage due to the favorable pH for bacterial growth. Bacterial growth on high-pH Wiltshire bacon has long been known to produce spoilage, which is recognized by the tainted flavor. Recent evidence has suggested that PSE pork and DFD (dark, firm, and dry) muscle in the pig are both associated with upsets in glycolysis and apparently are due to the same basic cause. The PSE condition is apparently due to immediate postmortem stimulation of glycolysis in the presence of adequate glycogen supplies, and results in abnormally low pH values. The DFD condition, on the other hand, is the result of long-standing stimulation resulting in complete disappearance of muscle glycogen while pH is still high. PSE muscle is objectionable because of its excessive shrinkage and pale color. DFD muscle is objectionable because of the dark color, and can also result in meat spoilage; thus it is even more serious than the PSE condition.

As already indicated, the amount of remaining glycogen in postmortem meat is quite low or even completely absent, so it has little effect on the nutritive value of meat and meat products. Some values for

TABLE 2.6. Calorie, Water, Protein, Fat, Carbohydrate and Ash Content of Some Canned Baby Foods Containing Meat, Expressed as Amount per 100 g Edible Portion[a]

Product Description	Calories	Water	Protein	Fat	Carbo-hydrate	Ash
Beef noodle dinner	48	88.2	2.8	1.1	6.8	1.1
Cereal, egg yolk and bacon	82	84.7	2.9	4.9	6.6	0.9
Macaroni, tomatoes, meat and cereal	67	84.5	2.6	2.0	9.6	1.3
Split peas, vegetables and ham or bacon	80	81.5	4.0	2.1	11.2	1.2
Vegetables and bacon with cereal	68	85.7	1.7	2.9	8.7	1.0
Vegetables and beef with cereal	56	87.0	2.7	1.6	7.6	1.1
Vegetables and chicken with cereal	52	87.8	2.1	1.4	7.7	1.0
Vegetables and ham with cereal	64	85.6	2.8	2.2	8.3	1.1
Vegetables and lamb with cereal	58	87.0	2.2	2.0	7.7	1.1
Vegetables and liver with cereal	47	87.8	3.1	0.4	7.8	0.9
Vegetables and liver with bacon and cereal	57	87.2	2.4	1.9	7.5	1.0
Vegetables and turkey with cereal	44	88.9	2.1	0.8	7.2	1.0
Beef with vegetables	87	81.6	7.4	3.7	6.0	1.3
Chicken with vegetables	100	79.6	7.4	4.6	7.2	1.2
Turkey with vegetables	86	81.3	6.7	3.2	7.6	1.2
Veal with vegetables	63	85.0	7.1	1.6	5.1	1.2
Beef—Strained	99	80.3	14.7	4.0	(0)	1.0
Beef—Junior	118	75.6	19.3	3.9	(0)	1.4
Beef Heart	93	81.1	13.5	3.8	(0)	1.2
Chicken	127	77.2	13.7	7.6	(0)	1.5
Egg yolks with ham or bacon	208	70.3	10.0	18.1	(0)	1.3
Lamb, Strained	107	79.3	14.6	4.9	(0)	1.2
Lamb, Junior	121	76.0	17.5	5.1	(0)	1.4
Liver, Strained	97	79.7	14.1	3.4	1.5	1.3
Liver and bacon, Strained	123	77.0	13.7	6.6	1.3	1.4
Pork, Strained	118	77.7	15.4	5.8	(0)	1.1
Pork, Junior	134	74.3	18.6	6.0	(0)	1.3
Veal, Strained	91	80.7	15.5	2.7	(0)	1.1
Veal, Junior	107	76.9	18.8	3.0	(0)	1.4

Source: USDA Handbook No. 8

[a] (0) indicates amount too small to measure

carbohydrate (chiefly glycogen) in various processed-meat items are shown in Tables 2.6 and 2.7. It is interesting to note that canned baby foods (Table 2.6), to which vegetables and/or cereal are added, have appreciable proportions of carbohydrate, although canned meats alone contain little or none. Similarly, Table 2.7 gives values for various processed-meat products and also shows that considerable carbohydrate content is present in some mixed items containing other foods. It is also interesting to observe the values for cured meat products, such as bacon and dried beef, in which sugar added during curing is reflected. For some unexplained reason, no carbohydrate was found in cured ham (Table 2.7), but appreciable amounts were found in canned ham (Table 2.4).

To summarize, the carbohydrate content of meat and meat products is usually negligible unless it is added during processing either as sugar or as other carbohydrate material. Nevertheless, the glycogen present at the time of slaughter, although it comprises only about 1%, plays a major role in determining the physical properties of meat.

Vitamins

Although the vitamins perform essential functions in man, serving as coenzymes in important life processes and in a variety of other body functions, lack of space precludes a detailed discussion. The reader is referred to the bibliography for more complete information. The material presented here will center on the levels present, their contribution to total dietary intake by man, and some effects of processing on the level in different meats and meat products.

The vitamins can be classified as fat-soluble and water-soluble. The fat-soluble group includes vitamins A, D, E, and K; the water-soluble group contains the B-complex vitamins and vitamin C. Generally speaking, meat is an excellent source of the B-complex vitamins and is poor in the fat-soluble group and vitamin C (ascorbic acid). However, the variety meats, especially liver and kidney, generally contain appreciable percentages of vitamins A, C, D, E, and K. Muscle is a poor source of A, C, D, E, and K, the small quantities present in fresh meat being largely destroyed during cooking and/or processing.

The vitamin content of meat is quite variable, being dependent on the species and age of the animal, the degree of fatness, and the type of feed furnished to the animal. The species difference is most notable when comparing the thiamine content of pork with that of beef or lamb, since pork contains 5 to 10 times more of this B-complex vitamin. The effect of diet can also be shown best by differences in the thiamine content of pork in which the diet is high in thiamine. Such supplementation may increase thiamine content severalfold. Since the water-soluble vitamins are localized in lean tissues and the fat-soluble vitamins in fatty tissues, the effect of the amount of fat per unit of meat is obvious. The greatest variation takes place in the B-complex vitamins, since neither the fat-soluble vitamins nor vitamin C are present in appreciable quantities per unit fat or lean, respectively. The effects of age will depend on the species and the particular vitamin in question. For example, veal is higher in thiamine, riboflavin, and niacin than beef. However, the young calf requires dietary B-complex vitamins during the early stages of growth, so veal could under certain circumstances be lower than beef.

The B-complex vitamins—thiamine, riboflavin, niacin, pantothenic acid, vitamin B_6, folic acid, biotin, and vitamin B_{12}—are all found in meats or variety meats. Meat and meat products contribute substantial amounts of B vitamins toward meeting the dietary requirements of man. Generally, liver is higher than lean meats. This is shown by examining the vitamin content for products containing liver, as illustrated in Tables 2.4 and 2.5.

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 on thawing also contains an appreciable portion of B vitamins (also of amino acids). This indicates the importance of conserving these fractions by making use of them in some way. Thiamine and, to a lesser extent, vitamin B_6 are heat-labile. These vitamins are partially destroyed during curing, smoking, cooking, canning, heat dehydration, and irradiation. Ionizing radiation causes losses as high as 60% for thiamine. Even mild curing and smoking result in destruction of about 15% of the thiamine. Typically, average losses of thiamine during cooking and processing of meat and meat products amount to about 25%.

Vitamin B_6 is more stable than thiamine, and heating results in losses normally equivalent to only about half the amount of thiamine. The high temperatures and time required in processing of canned meats results in less retention of these vitamins. Meat cut in thin pieces and cooked quickly retains a greater proportion of thiamine and B_6 than large roasts, where longer cooking times are required. Riboflavin and niacin are quite stable to conventional cooking and heat-processing. Some of these vitamins are lost in the drippings unless an effort is made to use them. Ionizing radiation may destroy most of the vitamin K, 25% of the riboflavin, and 10% of the niacin. Except for drip losses, freezing and frozen storage have little effect upon the vitamin levels. However, knowledge about the effects of cooking and processing upon pantothenic acid, biotin, folic acid, and vitamin B_{12} is limited. Some loss does appear to occur during cooking.

The concentration of vitamins in cooked meat and meat products is often higher than in raw meat. This can be seen by comparing the same product before and after cooking, as shown in Table 2.8. The higher values for the cooked products do not indicate that no losses occur during cooking, but rather that cooking drives off moisture and renders out fat. The net result is that the concentration of most of the

TABLE 2.7. Calorie, Water, Protein, Fat, Carbohydrate and Ash Content of Some Cured, Canned, or Processed Food Items Containing Meat, Chicken or Fish

Product Description	Calories	Water	Protein	Fat	Carbohydrate	Ash
Bacon						
slab or sliced, cured, raw	665	19.3	8.4	69.3	1.0	2.0
slab or sliced, cured, cooked and drained	611	8.1	30.4	52.0	3.2	6.3
cured and canned, unheated	685	16.7	8.5	71.5	1.0	2.3
Canadian, cured, unheated	216	61.7	20.0	14.4	0.3	3.6
Canadian, cured, cooked	277	49.9	27.6	17.5	0.3	4.7
Beef and vegetable stew, home cooked with lean beef chuck	89	82.4	6.4	4.3	6.2	0.7
Beef and vegetable stew, canned	79	82.5	5.8	3.1	7.1	1.5
Beef						
Roast, canned	224	60.0	25.0	13.0	0	2.0
Corned, boneless, medium fat, uncooked	293	54.2	15.8	25.0	0	5.0
Corned, boneless, medium fat, cooked	372	43.9	22.9	30.4	0	2.9
Corned, boneless, medium fat, canned	216	59.3	25.3	12.0	0	3.4
Corned Beef Hash with potato, canned	181	67.4	8.8	11.3	10.7	1.8
Dried and chipped, uncooked	203	47.7	34.3	6.3	0	11.6
Dried and chipped, creamed, cooked	154	72.0	8.2	10.3	7.1	2.4
Potpie, home prepared, cooked	246	55.1	10.1	14.5	18.8	1.5
Potpie, frozen, commercial, unheated	192	63.3	7.3	9.9	18.0	1.5

Chicken						
boneless meat, canned	198	65.2	21.7	11.7	0	1.4
a la King, home recipe, cooked	191	68.2	11.2	14.0	5.0	1.6
fricassee, home recipe, cooked	161	71.3	15.3	9.3	3.2	0.9
potpie, home prepared, cooked	235	56.6	10.1	13.5	18.3	1.5
potpie, frozen, commercial, unheated	219	57.8	6.7	11.5	22.2	1.8
and noodles, home recipe, cooked	153	71.1	9.3	7.7	10.7	1.2
Chili con carne with beans, canned	133	72.4	7.5	6.1	12.2	1.8
Chili con carne without beans (60% meat), canned	200	66.9	10.3	14.8	5.8	2.2
Chop suey with meat, canned	62	85.5	4.4	3.2	4.2	2.7
Chow mein, chicken without noodles, canned	38	88.8	2.6	0.1	7.1	1.4
Haddock, smoked, canned	103	72.6	23.2	0.4	0	3.1
Halibut, smoked	224	49.4	20.8	15.0	0	15.0
Ham						
Country style, dry cured, lean	310	49.0	19.5	25.0	0.3	5.8
commercially cured, medium fat, total edible, raw	282	56.5	17.5	23.0	0	3.0
commercially cured, medium fat, total edible, cooked	289	53.6	20.9	22.1	0	3.4
picnic, commercially cured, medium fat, total edible, raw	285	56.7	16.8	23.6	0	2.9
picnic, commercially cured, medium fat, total edible, cooked	323	48.8	22.4	25.2	0	3.6
canned, total contents of can	193	65.0	18.3	12.3	0.9	3.5
Pork and Gravy, (90% pork, 10% gravy), canned	256	56.9	16.4	17.8	6.3	2.6

Source: USDA Handbook No. 8

TABLE 2.8. Some Selected Values Showing the Mineral and Vitamin Contents of Various Grades and Cuts of Meat on a Raw and Cooked Basis, Expressed as Amount per 100 g Edible Portion

Product and Grade	Calcium (mg)	Phosphorus (mg)	Iron (mg)	Sodium[a] (mg)	Potassium[b] (mg)	Vit. A (I.U.)	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)	Ascorbic Acid (mg)
Beef carcass, total edible including kidney fat and kidney										
Good grade (66% lean, 34% fat), raw	10	152	2.5	65	355	60	0.07	0.15	4.0	—
Standard grade (73% lean, 27% fat), raw	10	166	2.7	65	355	40	0.08	0.16	4.3	—
Commercial grade (64% lean, 36% fat), raw	9	145	2.4	65	355	60	0.07	0.14	3.8	—
Utility grade (76% lean, 24% fat), raw	11	172	2.8	65	355	40	0.08	0.17	4.5	—
Beef round, Choice grade, separable lean, raw	13	217	3.2	65	355	10	0.09	0.19	5.2	—
Beef round, Choice grade, separable lean, cooked	13	268	3.7	60	370	10	0.08	0.24	6.0	—
Beef chuck, Choice grade, separable lean, raw	12	214	3.2	65	355	10	0.09	0.19	5.1	—
Beef chuck, Choice grade, separable lean, cooked	13	160	3.8	60	370	20	0.05	0.23	4.6	—
Lamb, composite of cuts (leg, loin, rib, and shoulder) trimmed, Good grade (79% lean, 21% fat), raw	10	151	1.3	75	295	—	0.15	0.21	4.9	—
Lamb leg, Good grade, separable lean, raw	12	185	1.8	75	295	—	0.18	0.25	5.8	—
Lamb leg, Good grade, separable lean, cooked	12	238	2.2	70	290	—	0.16	0.30	6.2	—
Lamb shoulder, Good grade, separable lean, raw	11	170	1.6	75	295	—	0.16	0.23	5.3	—
Lamb shoulder, Good grade, separable lean, cooked	11	219	1.9	70	290	—	0.15	0.28	5.7	—
Pork carcass, thin (53% lean, 47% fat), raw	6	116	1.7	70	285	(0)	0.54	0.13	2.9	—
Pork carcass, thin, separable lean, raw	11	210	2.7	70	285	(0)	0.89	0.21	4.8	—
Pork shoulder, thin (75% lean, 25% fat), raw	8	148	2.0	70	285	(0)	0.66	0.16	3.5	—
Pork ham, trimmed, thin (77% lean, 23% fat), raw	10	190	2.5	70	285	(0)	0.82	0.20	4.4	—
Pork ham, trimmed, thin (77% lean, 23% fat), cooked	11	252	3.2	65	390	(0)	0.54	0.25	4.8	—
Pork ham, thin, separable lean, raw	12	238	3.1	70	285	(0)	0.99	0.24	5.3	—
Pork ham, thin, separable lean, cooked	13	315	3.8	65	390	(0)	0.66	0.30	5.8	—
Veal carcass, thin (86% lean, 14% fat), raw	11	199	2.9	90	320	—	0.14	0.26	6.5	—
Veal chuck, thin (90% lean, 10% fat), raw	12	206	3.0	90	320	—	0.15	0.26	6.7	—
Veal round and rump, thin (91% lean, 9% fat), raw	12	206	3.0	90	320	—	0.15	0.26	6.7	—

Source: USDA Handbook No. 8

[a] Average values are given for the respective type meat, raw or cooked as the case may be.

[b] Average values are given for respective type meat, raw or cooked as the case may be.

0 indicates too small amount to be measured

—indicates no reliable data

B-complex vitamins per unit weight increases during cooking and processing.

NUTRITIONAL VALUE OF SOME PROCESSED MEATS

Although the nutritional value of some fresh meats used for processing (Tables 2.1 and 2.8) and of some meat products (Tables 2.4 and 2.5) has already been presented, additional values for other products should be useful. Table 2.9 gives data on some cured, canned, or processed meat items. The same data are presented for some sausages and other canned products in Table 2.10. Such data should be useful for estimating the contribution of meat toward meeting the dietary requirements of man. Although much more information is needed on the nutritive value of meat and meat products, the information included in Tables 2.9 and 2.10 provides a beginning for some meat items that are not well understood as to their nutritive value.

TOXIC COMPOUNDS IN MEAT PRODUCTS

Although meat products generally are recognized as making important contributions to human health, in some instances toxic components may be present in meats. Processors should be aware of these possibilities and make every effort to avoid the presence of these toxicants. The toxic components may come from (1) naturally occurring substances in meat and meat foods, (2) microbial agents, (3) pesticide residues, (4) food additives, and (5) substances produced during processing.

Some of the components naturally present in meat that may be potentially harmful to man have already been discussed in this chapter. These include cholesterol and the carcinogens created by certain cooking procedures from the lipids in meat and meat products. Some of the products of lipid oxidation seem to be responsible for at least part of the adverse effects of lipids.

There are a great many pathogenic and toxigenic microorganisms that can grow on meat products. Processors should take all necessary precautions to control such organisms, which include *Salmonella* spp., *Clostridium botulinum, Clostridium perfringens, Staphylococcus aureus, Shigella* spp., and *Vibrio parahaemolyticus* among others. In addition, molds can also produce mycotoxins that may be carried over from contaminated feeds to the meat of animals consuming them. There are a number of mycotoxins, the best known of which are aflatoxins and ochratoxins. Although these highly toxic compounds can be present in fresh meats, their presence is primarily a meat production

TABLE 2.9. Mineral and Vitamin Content of Some Cured, Canned or Processed Food Products Containing Meat, Chicken and Fish[a]

Product Description	Calcium (mg)	Phosphorus (mg)	Iron (mg)	Sodium (mg)	Potassium (mg)	Vit. A (I.U.)	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)	Ascorbic Acid (mg)
Bacon										
slab or sliced, cured, raw	13	108	1.2	680	130	(0)	0.36	0.11	1.8	—
slab or sliced, cured, cooked and drained	14	224	3.3	1,021	236	(0)	0.51	0.34	5.2	—
cured and canned, unheated	15	92	1.4	—	—	(0)	0.23	0.10	1.5	—
Canadian, cured, unheated	12	180	3.0	1,891	392	(0)	0.83	0.22	4.7	—
Canadian, cured, cooked	19	218	4.1	2,555	432	(0)	0.92	0.17	5.0	—
Beef & vegetable stew, home-cooked with lean beef chuck	12	75	1.2	37	250	980	0.06	0.07	1.9	7
Beef and vegetable stew, canned	12	45	0.9	411	174	970	0.03	0.05	1.0	3
Beef										
roast, canned	16	116	2.4	—	259	—	0.02	0.23	4.2	0
corned, boneless, medium fat, uncooked	9	125	2.4	1,300	60	—	0.03	0.15	1.7	0
corned, boneless, medium fat, cooked	9	93	2.9	1,740	150	—	0.02	0.18	1.5	0
corned, boneless, medium fat, canned	20	106	4.3	—	—	—	0.02	0.24	3.4	0
corned beef hash with potato, canned	13	67	2.0	540	200	—	0.01	0.09	2.1	—
dried and chipped, uncooked	20	404	5.1	4,300	200	—	0.07	0.32	3.8	0
dried and chipped, creamed, cooked	105	140	0.8	716	153	360	0.06	0.19	0.6	Trace
potpie, home-prepared, cooked	14	71	1.8	284	159	820	0.11	0.12	2.0	3
potpie, frozen, commercial, unheated	10	48	1.0	366	93	410	0.03	0.06	1.2	Trace

Chicken										
boneless meat, canned	21	247	1.5	—	138	230	0.04	0.12	4.4	4
a la King, home recipe, cooked	52	146	1.0	310	165	460	0.04	0.17	2.2	5
fricassee, home recipe, cooked	6	113	0.9	154	140	70	0.02	0.07	2.4	0
potpie, home-prepared, cooked	30	100	1.3	256	148	1,330	0.11	0.11	1.8	2
potpie, frozen, commercial, unheated	11	50	1.0	411	153	910	0.10	0.14	1.4	4
and noodles, home recipe, cooked	11	103	0.9	250	62	180	0.02	0.07	1.8	Trace
Chili con carne with beans, canned	32	126	1.7	531	233	60	0.03	0.07	1.3	—
Chop Suey with meat, canned	35	116	1.9	551	138	30	0.05	0.05	0.7	2
Chow Mein, chicken without noodles, canned	18	34	0.5	290	167	60	0.02	0.04	0.4	5
Haddock, smoked, canned	—	—	—	—	—	—	0.06	0.05	2.1	—
Halibut, smoked	—	—	—	—	—	—	—	—	—	—
Ham										
Country style, dry-cured, lean	—	—	—	—	—	(0)	—	—	—	—
commercially cured, medium fat, total edible, raw	10	162	2.6	—	—	(0)	0.72	0.19	4.1	—
commercially cured, medium fat, total edible, cooked	9	172	2.6	—	—	(0)	0.47	0.18	3.6	—
picnic, commercially cured, medium fat, total edible, raw	10	150	2.5	—	—	(0)	0.69	0.19	3.9	—
picnic, commercially cured, medium fat, total edible, cooked	10	182	2.9	—	—	(0)	0.52	0.20	4.0	—
canned, total contents of can	11	156	2.7	1,100	340	(0)	0.53	0.19	3.8	—
Pork and gravy (90% pork, 10% gravy) canned	13	183	2.4	—	—	(0)	0.49	0.17	3.5	—

Source: USDA Handbook No. 8

[a] —indicates no values available; (0) indicates probably none or too small to measure.

TABLE 2.10. Mineral and Vitamin Content of Some Sausages and Canned Meat Items[a]

Product Description	Calcium (mg)	Phosphorus (mg)	Iron (mg)	Sodium (mg)	Potassium (mg)	Vit. A (I.U.)	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)	Ascorbic Acid (mg)
Blood sausage or blood pudding	—	—	—	—	—	—	—	—	—	—
Bockwurst	—	—	—	—	—	—	—	—	—	—
Bologna										
all samples	7	128	1.8	1,300	230	—	0.16	0.22	2.6	—
all-meat	—	—	—	—	—	—	—	—	—	—
with nonfat dry milk	—	—	—	—	—	—	—	—	—	—
Braunschweiger	10	245	5.9	—	—	6,530	0.17	1.44	8.2	—
Brown and Serve Sausage										
before browning	—	—	—	—	—	—	—	—	—	—
after browning	—	—	—	—	—	—	—	—	—	—
Capicola	—	—	—	—	—	—	—	—	—	—
Cervelat, dry	14	294	2.7	—	—	(0)	0.27	0.23	5.5	—
Country style sausage (pork sausage, smoked)	9	168	2.3	—	—	—	0.22	0.19	3.1	—
Deviled ham, canned	8	92	2.1	—	—	(0)	0.14	0.10	1.6	—
Frankfurters										
all samples, unheated	7	133	1.9	1,100	220	—	0.16	0.20	2.7	—
all meat, unheated	—	—	—	—	—	—	—	—	—	—
with nonfat dry milk, unheated	—	—	—	—	—	—	—	—	—	—
heated or cooked	5	102	1.5	—	—	—	0.15	0.20	2.5	—
canned	9	145	2.2	—	—	—	0.03	0.12	2.4	—

Headcheese	9	173	2.3	—	—	(0)	0.04	0.10	0.9	—
Knockwurst	8	154	2.1	—	—	—	0.17	0.21	2.6	—
Liverwurst										
fresh	9	238	5.4	1	1	6,350	0.20	1.30	5.7	—
smoked	10	245	5.9	—	—	6,530	0.17	1.44	8.2	—
Luncheon meat										
boiled ham	11	166	2.8	—	—	(0)	0.44	0.15	2.6	—
chipped, spiced pork	9	108	2.2	1,234	222	(0)	0.31	0.21	3.0	—
Meat loaf	9	178	1.8	—	—	—	0.13	0.22	2.5	—
Meat, potted (beef, chicken, or turkey)	—	—	—	—	—	—	0.03	0.22	1.2	—
Minced ham	8	89	2.1	—	—	(0)	0.37	0.22	3.4	—
Mortadella	12	238	3.1	—	—	—	—	—	—	—
Polish style sausage	9	176	2.4	—	—	(0)	0.34	0.19	3.1	—
Pork sausage										
link or bulk, raw	5	92	1.4	740	140	(0)	0.43	0.17	2.3	—
link or bulk, cooked	7	162	2.4	958	269	(0)	0.79	0.34	3.7	—
Salami										
dry	14	283	3.6	—	—	—	0.37	0.25	5.3	—
cooked	10	200	2.6	—	—	—	0.25	0.24	4.1	—
Scrapple	5	64	1.2	—	—	—	0.19	0.09	1.8	—
Souse	—	—	—	—	—	(0)	—	—	—	—
Thuringer	11	214	2.8	—	—	—	0.11	0.26	4.2	—
Vienna Sausage, canned	8	153	2.1	—	—	—	0.08	0.13	2.6	—
Turkey, meat only, canned	10	—	1.4	—	—	130	0.02	0.14	4.7	—

Source: USDA Handbook No. 8

[a] —indicates lack of reliable data; (0) indicates none or too small to measure.

problem. Aflatoxins can, however, occur in cured meat and sausages stored under conditions favoring the growth of molds. Such storage conditions should be eliminated.

Pesticide residues and food additives are commonly believed to constitute serious hazards in foods, especially in meats. These two classes of compounds, however, do not generally constitute serious problems, as long as processors are judicious in using them or in adding them to meat products. Nitrites and nitrosamines have been mentioned frequently by the public media as causing serious health hazards, yet there is little evidence supporting this viewpoint. Their significance is discussed in Chapter 3 in greater detail. Sodium chloride or common salt has been referred to earlier in the present chapter.

Substances produced during processing of meat include lipid oxidation products and compounds produced by the Maillard reaction. Although some of these compounds have been shown to be mutagenic and/or carcinogenic, their significance is not fully understood. Cooking of hamburgers has been reported to produce mutagens, but further work will be necessary to assess fully their presence and/or significance in processed meats.

SUMMARY

Meat and meat products are generally excellent sources of protein, containing a good balance of the essential amino acids and having a high biological value. The connective-tissue proteins are exceptions and should be used in limited quantities. Meat is also a good source of most B-complex vitamins, but is usually low in the fat-soluble vitamins (A, D, E, and K) and in vitamin C. Liver and other organ meats are generally higher in B-complex and fat-soluble vitamins than muscle. Meat is a good source of phosphorus and iron, but is low in calcium. Meat also contributes significant percentages of a number of other minerals, including copper, zinc, sodium, potassium, and magnesium.

Although the carbohydrate content of meat is relatively low and may disappear completely during development of rigor mortis, the glycogen content of meat plays a key role in determining the physical properties of meat and meat products. Thus, glycogen was discussed from the standpoint of its role in glycolysis and the effects on the properties of meat products.

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3

Curing

Although salt was used for preserving fish as far back as 3500 B.C., the origin of its use in curing meat is lost in antiquity. Homer in the *Odyssey,* written about the eighth century B.C., describes sausage made by adding salt to meat. By the fifth century B.C., production of salted meat products had become commonplace. Ancient man was well aware of the preservative action of salt, which was probably discovered by accident. It is also probable the color-preserving properties of saltpeter (nitrate) were discovered as a result of its presence as an impurity in salt.

Early dry cured meat products were extremely variable in quality, often being too salty and lacking in uniformity of cure. Scientific principles were not applied to meat curing until the latter half of the nineteenth century, when the growing meat packing industry began to find ways of improving quality. Present rapid curing methods, such as brine injection procedures, are of more recent origin. They were not used commonly until the 1940s. Many innovations have occurred in meat curing during the last 35 years, which have been made possible by advances in equipment design and greater mechanization.

Meat curing was used originally almost entirely as a means of preserving meat during times of plenty to carry over to times of scarcity. Until the successful advent of refrigeration and its availability in the home, curing continued to be designed solely as a means of preservation. The almost universal availability of home refrigerators has, however, greatly altered the reasons for curing. Today, cured meat products are generally mild-cured and must be stored under refrigeration. This chapter deals primarily with the curing of primal meat cuts; but the cure ingredients, together with the discussion of cured meat color development, apply to sausage and cured canned meats as well.

INGREDIENTS UTILIZED IN MEAT CURING

Although a variety of compounds can be used in curing meat, the basic curing ingredients are salt, sugar or some other sweetener, and nitrite and/or nitrate. In addition, phosphates are commonly added to pickle cures in commercial operations. A number of other compounds are sometimes used in curing mixtures, such as various spices, baking soda, sodium erythorbate, hydrolyzed vegetable proteins, and monosodium glutamate.

Salt

Salt is basic to all curing mixtures and is the only ingredient necessary for curing. Salt acts by dehydration and altering of the osmotic pressure so that it inhibits bacterial growth and subsequent spoilage. Use of salt alone, however, gives a harsh, dry, salty product that is not very palatable. In addition, salt alone results in a dark, undesirable colored lean that is unattractive and objectionable to consumers.

As a consequence of undesirable effects of salt on flavor and appearance, it is generally used in combination with both sugar and nitrite and/or nitrate. A limited number of products still are sometimes cured with salt alone. Cuts cured in this way are strictly fatty cuts containing little if any lean tissue. Cuts such as clear plates, fat backs, jowls, or heavy bellies that are intended for seasoning of other food products, including pork and beans, may occasionally be cured with salt alone. Even in the case of such fatty cuts, nitrite and/or nitrate is sometimes used. When salt is used alone, it is added in excess since the extreme saltiness is commonly modified by cooking with other food products.

Only food-grade salt should be used in curing, since impure salt can cause flavor and color problems. Although dry salt curing utilizes salt in excess, the amount used in other dry-curing methods and pickles is variable, depending upon the end product desired. Pickle cures vary from 50° to 85°, 65° pickles being most common. An acceptable level of salt in hams has been reported to be about 3% and about 2% for bacon. Of course, higher and lower salt levels are common and are a matter of personal preference.

Recently, emphasis has been placed on reducing levels of salt in meat products in view of its relationship to hypertension in about 20% of the population. Thus, processors are attempting to decrease salt in most meat products. Since the sodium is the element in salt that causes hypertension, other chloride-containing salts are being considered as alternatives to sodium chloride. Most of the salt substitutes taste bitter and must be used at lower levels than salt. A combination of sodium chloride and potassium chloride at a 1:1 ratio shows some promise for replacing ordinary salt. Higher levels of potassium chloride have an unacceptable bitter taste. Reduction or replacement of sodium chloride should be done with caution since little is known about their long range effects on either preservation or human health.

Sugar and Corn Syrup Solids

The addition of sugar to cures is primarily for flavor. Sugar softens the products by counteracting the harsh hardening effects of salt by preventing some of the moisture removal and by a direct moderating action on flavor. Sugar also interacts with the amino groups of the proteins and, when cooked, forms browning products that enhance the flavor of cured meats. In some instances, the browning reaction may become too pronounced and burned flavors result. Sugar substitutes have been used in bacon cures to prevent excessive browning during cooking. Corn syrup, molasses, and other natural sugar substitutes are sometimes used in place of sugar. The extent of substitution is largely a matter of cost after determining the relative effects on flavor and color.

Sugar, also, is an effective preservative and will retard bacterial growth. However, the level used in meat curing is so low it is doubtful that sugar has any major influence on the bacteria. Some people have claimed that sugar supports the growth of desirable flavor-producing bacteria, but there is no evidence to support this viewpoint.

The proportion of sugar used in curing varies widely in commercial operations. Most processors use only 20–30 lb per 100 gal of brine. At this level, sugar probably plays only a minor role in flavor development. Carefully controlled studies have suggested that consumers prefer about 2% sugar in cured hams. This would require about 160 lb sugar per 100 gal brine. Unfortunately, similar data are not available for other products.

Corn syrup or corn syrup solids are frequently substituted for sugar. As the names imply, corn syrup solids consist of corn syrup from which most of the water has been removed, while corn syrup contains a higher level of moisture. Either corn syrup or corn syrup solids may be purchased in bulk quantities. Since they differ only in the amount of moisture, they will be considered together without differentiation.

Corn syrup is composed of a mixture of sugars formed by breakdown of starch and contains dextrose, maltose, higher sugars, dextrins, and polysaccharides. Corn syrup is not as sweet and is less soluble than sugar. However, both corn syrup solids and corn syrup are used widely in curing meat because they cost considerably less. The amount of corn syrup solids is limited to 50 lb per 100 gal brine under federal inspection regulations. Furthermore, the amount of corn syrup or sugars present in any seasonings added to the cure must also be considered in the total.

Nitrite and/or Nitrate

The function of nitrite in meat curing is fourfold: (1) to stabilize the color of the lean tissues, (2) to contribute to the characteristic flavor of cured meat, (3) to inhibit growth of a number of food poisoning and spoilage microorganisms, and (4) to retard development of rancidity. Although color stabilization was originally the primary purpose of adding nitrite to curing mixtures, its effects on flavor and inhibition of bacterial growth are even more important. Nevertheless, the attractive pink-red color of cured meat adds to its desirability. The effect of nitrite on the flavor of cured meat has only recently been demonstrated. However, the most important reason for adding nitrite to meat cures appears to be its effect on microbial growth. It has been clearly demonstrated that nitrite is effective in preventing the growth of the *Clostridium botulinum* organism. Evidence also suggests the levels of nitrite found in cured meat may also aid in preventing the growth of other spoilage and food poisoning organisms.

Nitrate serves principally as a source of nitrite. Although nitrate was originally approved for color fixation in cured meats, it has largely been replaced by nitrite. It is now only used in a few products, such as country cured hams and Lebanon bologna.

The maximum levels of nitrite and nitrate allowed in different types of cured meat products are given in Table 3.1, as are the maximum

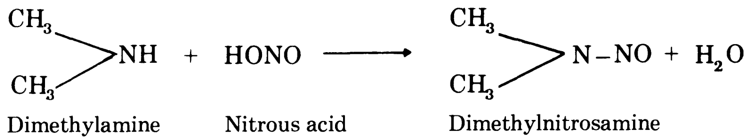
TABLE 3.1. Levels of Nitrite and/or Nitrate Allowed in Curing Different Meat Products[a]

	Maximum levels		
Product	Ingoing level as $NaNO_2$ (ppm)	Ingoing level as $NaNO_3$ (ppm)	Residual levels allowed as $NaNO_2$ (ppm)
Bacon-pumped	120[b]	None	No Control
Bacon-immersion cured	200[c]	700[d]	200
Cooked sausage	156[e]	1719[f]	200
Dry and semidry sausage	156[e]	1719[f]	200
Dry cured cuts	625[g]	2188[h]	200
Pickle cured cuts (canned and uncanned)	200[i]	700[d]	200
Shelf stable, sterile canned comminuted products	156[e]	1719[f]	200
Baby foods: Junior and Toddler meats	None	None	None

[a] Table gives maximum ingoing levels of nitrite and nitrate and maximum residual levels as sodium nitrite in various type meat products in USDA regulations as of 1983.
[b] 550 ppm ascorbate or erythorbate is also required.
[c] The regulation actually reads "2 lbs. to 100 gal. pickle".
[d] The regulation actually reads "7 lbs. to 100 gal. pickle".
[e] The regulation actually reads "¼ oz. to 100 lbs. chopped meat and/or meat by-product".
[f] The regulation actually reads "2¾ oz. to 100 lbs. chopped meats". Most processors have discontinued use of nitrate in these products even though it is permitted, except in Lebanon bologna.
[g] The regulation actually reads "1 oz. to 100 lbs. meat (dry cured)".
[h] The regulation actually reads "2 lbs. to 100 gal. pickle at 10 percent pump level". It assumes 10 lbs./gal.
[i] The regulation actually reads "3½ oz. to 100 lbs. chopped meat (dry cured)". Nitrate is used in these products to a greater extent than in comminuted products required to have the "Keep Refrigerated" statement on the label.

allowable levels of nitrite in the finished products. The latter includes nitrate but is calculated in terms of total sodium nitrite. Although nitrates are allowed in a considerable number of products, in practice sodium nitrate is commonly used only in country hams, Lebanon bologna, and shelf-stable sterile canned comminuted products. It is significant, however, that use of both nitrite and nitrate is prohibited in canned baby meats.

Nitrosamines. The reaction of nitrous acid (which is formed by the breakdown of nitrite) with secondary amines to produce nitrosamines is a well-known reaction in organic chemistry. The reaction of nitrous acid with dimethylamine is:



Nitrosamines have been isolated in small amounts from nearly all cured meat products, apparently as a result of the interaction of nitrite with secondary amines during curing and/or cooking. Since nitrosamines have been shown to be carcinogenic, their presence in meat products comes under Delaney Amendment of the Pure Food and Drug Act, which clearly states that any food additive causing cancer must be removed from the food supply. The Food and Drug Administration has worked closely with the meat industry to develop processing procedures that would eliminate nitrosamines from cured meats, but would still permit retention of nitrite in view of its action in preventing the outgrowth of *Clostridium botulinum* and other food-poisoning organisms. It has generally been conceded that the risks from low levels of nitrosamines are less than those from botulism poisoning, which may occur if nitrites were removed from the cure. It has been shown that combining of nitrite with the other curing agents and seasoning ingredients can result in nitrosamine formation in meat curing premixes. The FDA has taken steps to eliminate this problem by requiring that nitrite be packaged separately from the seasoning ingredients.[1] Formation of *N*-nitrosopyrrolidine during the frying of bacon has been the major problem from nitrosamines in processed meats. However, it has recently been reported that the problem can be largely eliminated by using α-tocopherol-coated salt in the cure.

[1]The FDA ordered on July 19, 1973 manufacturers of meat curing premixes which combine nitrite curing agents with seasoning to package the nitrite and seasoning separately to eliminate the possibility of nitrosamine formation in premixes. The FDA action will not affect manufacturers who use a chemical "buffer" to separate the nitrite and the seasoning in a premix. Nitrosamines have not been found in such premixes, which constitute a majority of such products now in use. As a safety precaution, however, FDA is requiring any manufacturer who wishes to market such premixes to submit a food additive petition as further assurance that the premixes are free of nitrosamines.

Nitrite per se has been reported to be carcinogenic above and beyond its possible role in formation of nitrosamines. The FDA proposed reducing and eliminating nitrite in meat curing as a consequence of these studies. A thorough review of the evidence was undertaken by a Committee of the National Academy of Sciences, which suggested more research was needed on the role of nitrite in meat curing in view of its beneficial effects in cured meats.

More careful control of processing parameters and the level of nitrite in the cure have lowered the levels of nitrosamines until they are absent or barely detectable (a few parts per billion) in most cured products. Bacon has been the one product in which nitrosamines have been most difficult to eliminate. This is because they are formed during the cooking process, with a combination of high temperatures during cooking and the presence of nitrite and secondary amines contributing to their formation. Recent research has demonstrated that sodium ascorbate at a level of 550 ppm in combination with 120 ppm of sodium nitrite will materially reduce nitrosamines in cured, cooked bacon. It has also recently been suggested that addition of potassium sorbate to the cure may be used to further reduce formation of nitrosamines. These recent studies suggest that it should be possible to further reduce nitrosamine formation in processed meats.

Levels of Nitrite and/or Nitrate. Nitrates were used as the only color-stabilizing element for meat curing until 1925. At that time, the U.S. Department of Agriculture also approved the use of sodium nitrite.

Federal meat inspection regulations permit the use of the following quantities of nitrate: 7 lb to 100 gal pickle, 3½ oz to 100 lb meat (dry cure), and 2¾ oz to 100 lb chopped meat. The same regulations permit use of nitrite at the following levels: 2 lb to 100 gal pickle at 10% pump level, 1 oz to 100 lb meat (dry cure), ¼ oz to 100 lb chopped meat. The regulations further state that the use of nitrite or nitrate, or a combination of both, shall not result in more than 200 ppm nitrite in finished products. The legal level permitted is sometimes less than the residual level allowed. This is evident in the case of the ¼ oz nitrite permitted in 100 lb chopped meat, which is only 156 ppm at the time of formulation.

Nitrite levels in curing of bacon have been reduced to an in-going level of 120 ppm of nitrite in combination with 550 ppm of sodium ascorbate. This level of ascorbate in combination with α-tocopherol-coated salt has been shown to greatly reduce *N*-nitrosamine formation during frying of bacon.

Phosphates

Phosphates are added to the cure to increase the water-binding capacity and thereby the yield of finished product. The action of phosphates in improving water retention appears to be twofold: (1) raising the pH and (2) causing an unfolding of the muscle proteins, thereby making more sites available for water binding. Only alkaline phosphates are effective for improving water binding since acid phosphates may lower the pH and cause greater shrinkage.

Phosphates will improve the retention of brine, and improvements in yields have been noted. With addition of phosphates to pumping brines, it is not difficult to obtain finished yields for intact hams and shoulders of over 100%.

Phosphates also chelate trace metal ions and retard development of rancidity in meat products. The effects of phosphates in sausage products are covered in greater detail in Chapter 11.

Because of the corrosive nature of phosphates, the equipment utilized must be made of stainless steel or plastic. Canned hams pumped with phosphates should always be placed in anodized cans, where an aluminum insert is selectively corroded and the can per se is protected, or wrapped in polyethylene film. Another problem sometimes encountered in utilizing phosphates has been the occurrence of crystals on the surface of the cured products. Such crystals have been identified as disodium phosphates. The excess salt appears to be due to hydrolysis of the polyphosphates by the natural phosphatase in meat. Prevention of the condition can be achieved by reducing the level of phosphate in the cure and maintaining a high relative humidity in the product environment.

Tripolyphosphates have been the most widely used of all the phosphates utilized in meat curing. Most recently, it has been shown there are advantages in using alkaline compounds in combination with tripolyphosphates in regard to increasing finished yields for hams and other cured products. Apparently, the other alkaline compounds increase the effectiveness over that of tripolyphosphate alone. Their action is probably synergistic and in some way increases water binding. The compounds utilized have not been fully described since the new combination product is patented and sold under a trade mark.

Although some claims have been made that phosphates improve color retention and flavor, there is little evidence to support such viewpoints except for their effect in retarding rancidity.

Sodium tripolyphosphate, sodium hexametaphosphate, sodium acid pyrophosphate, sodium pyrophosphate, and disodium phosphate have all been approved for production of cured primal cuts, but only sodium acid pyrophosphate is permitted in sausages. Legal limits for added residual phosphates are set at 0.5% in the finished product. Since meat contains 0.01% of natural phosphate, this must be subtracted in calculating the level added during curing.

Sodium Ascorbate and Erythorbate

The salts of ascorbic acid and erythorbic acid are commonly used to hasten development and stabilize the color of cured meat. In practice, only sodium erythorbate or sodium ascorbate are used in curing pickles, since ascorbic or erythorbic acid reacts with the nitrite to form nitrous oxide. Since nitrous oxide is dangerous in confined spaces and the nitrite is destroyed, ascorbates are always used under practical conditions. This group of compounds, which will be referred to as ascorbates during the remainder of this discussion, serves three main functions: (1) ascorbates take part in the reduction of metmyoglobin to myoglobin, thereby accelerating the rate of curing; (2) ascorbates react chemically with nitrite to increase the yield of nitric oxide from nitrous acid; (3) excess ascorbate acts as an antioxidant, thereby stabilizing both color and flavor; and (4) under certain conditions ascorbates have been shown to reduce nitrosamine formation.

Although ascorbate has been used by meat processors to speed up processing and to prevent fading, an even more important use may be its effect in reducing nitrosamine formation. At a level of 550 ppm, ascorbate has been shown to reduce or eliminate nitrosamine formation. The exact mechanism is not known, but current meat inspection regulations specify that all bacon be produced using no more than 120 ppm of nitrite in combination with 550 ppm of ascorbate.

Ascorbate may be used in both intact cuts and sausages, but the greatest advantage of its use is in sausages, where the time of processing can be greatly reduced; in processing frankfurters, the time can be reduced by one-third if ascorbates are added. This eliminates the waiting period normally needed for breakdown of nitrite and formation of the stable pink pigment in the absence of ascorbate. If ascorbate is added to the cure, emulsion-type products can go directly into the smokehouse after stuffing, without waiting for color development.

The antioxidant properties of ascorbate not only prevent development of rancidity, but also prevent fading of sliced meats when exposed to light. Protection is closely associated with prevention of heme-catalyzed lipid oxidation, which results in both pigment degradation and development of rancidity. As long as excess ascorbate is present, the pigments are protected against breakdown. When ascorbate is depleted, however, the heme pigments are degraded and apparently catalyze lipid oxidation.

Federal regulations permit addition of 0.75 oz ascorbic acid or erythorbic acid (0.875 oz sodium ascorbate or erythorbate) per 100 lb sausage emulsion, or addition of 75 oz (87.5 oz of sodium salts) per 100 gal pickle for curing primal cuts. Pickles containing both sodium nitrite and sodium ascorbate are stable for at least 24 hr when maintained at 50°F and pH 6.0 or higher. However, longer periods of storage are not advisable, and if the pickle is to be stored for extended periods, it should be analyzed and the necessary ascorbate added to bring it back to the original concentration.

Potassium Sorbate

Sorbic acid and its potassium salt, potassium sorbate, are antimicrobial agents that have been widely used as food preservatives.

These compounds are particularly effective in inhibiting mold growth and have been extensively utilized for this purpose in fish, dairy, and bakery products. Potassium sorbate is generally preferred in food systems because of its great solubility in water. Sorbate is on the GRAS list since it is readily metabolized and relatively nontoxic.

The only presently approved use of sorbate in meat products is as a 2.5% solution of potassium sorbate for dipping of stuffed dry sausages, where it inhibits mold growth on the casings. Sorbate has also been shown to be a potent inhibitor of *Clostridium botulinum,* especially when used in combination with low levels of nitrite. In 1979, USDA meat inspection regulations were proposed that would have allowed the use of 0.26% of potassium sorbate in combination with 40 ppm of sodium nitrite for production of cured bacon. The proposed regulation was withdrawn since allergenic reactions were reported by some individuals during sensory evaluation of bacon prepared using sorbate. Although the effectiveness of the nitrite and sorbate combination in controlling botulism has been verified in many studies, the question as to its possible allergenic reactions still remains unresolved. Should sorbate be cleared of causing allergies, it will no doubt be widely utilized for reducing the levels of nitrite in cured meat.

Monosodium Glutamate

Monosodium glutamate (MSG) has been used in a number of products to enhance the flavor. It has not, however, been widely used in the meat industry as there is little advantage in its use in good meat products, although mixed meat dishes may profit from its meat flavor-enhancing properties.

Hydrolyzed Vegetable Proteins

Addition of hydrolyzed vegetable proteins (HVP) to sausages and other meat products has been utilized by some processors. HVP is said to improve flavor and effectively increase the protein content. Its use in meat products has, however, gained little acceptance by the processing industry. It is used most commonly in kosher sausage products. Some smaller processors have also used HVP in cured hams.

CURED MEAT COLOR

In order to understand color development during meat curing, it is necessary to have knowledge of the pigments in muscle and the chemical reactions they undergo during curing. Color develops as a result of the interaction of nitrites with the muscle pigments. Thus, the structure and importance of the pigments will be discussed in light of their reactions and their effects on meat color.

Muscle Pigments

There are a number of muscle pigments in meat, including myoglobin, hemoglobin, the cytochromes, catalase, the flavins, and other colored substances. Quantitatively, the first two listed, myoglobin and hemoglobin, are by far the most abundant. Although the lesser pigments could play key roles in color development and stabilization, most of our knowledge about meat color deals with myoglobin and hemoglobin.

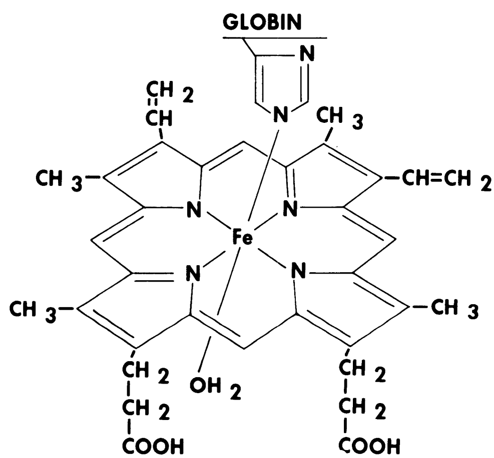
Myoglobin and hemoglobin are both complex proteins that undergo similar reactions in meat. However, their roles in living tissue are quite different. Hemoglobin is the red pigment found in blood and acts as the carrier for oxygen to the tissues. Myoglobin is the predominant pigment in muscle and serves as the storage mechanism for oxygen at the cellular level. Because of the differences in function, myoglobin has a greater affinity for oxygen. This can be shown by exposing a freshly cut surface of meat to air, as manifested by the rapid brightening in color as the myoglobin takes up oxygen.

Although hemoglobin is the predominant pigment in the living animal, after slaughter by bleeding, myoglobin becomes the major pigment. Myoglobin accounts for only 10% of the total iron in the live animal, but after bleeding, may account for as much as 95% of the iron in beef skeletal muscle. Nevertheless, hemoglobin is still present in appreciable quantities and may play an important part in meat color.

The amount of myoglobin and hemoglobin in various tissues varies with (1) amount of muscular activity of the tissue, (2) blood supply, (3) oxygen availability, and (4) age of the animal. Tissues having a high degree of muscular activity tend to have greater proportions of both myoglobin and hemoglobin. For example, the heart is the most active muscle in the body and contains relatively large amounts of both hemoglobin and myoglobin by virtue of its high oxygen requirements. Tissues with a relatively good blood supply tend to have more hemoglobin and relatively less myoglobin than muscles having a poorer oxygen supply. This is evident in the wing muscles of birds where the demands for oxygen are largely supplied by an efficient circulatory system. If the tissues are able to store large quantities of oxygen, the myoglobin content is relatively high and the hemoglobin content relatively low. The whale has the ability to store large quantities of oxygen because of its extremely high myoglobin content, and thus can remain submerged for extended periods of time. In regard to age, the young animal has less myoglobin and relatively more hemoglobin than older animals of the same species. This is shown by the following values for myoglobin for fresh bovine skeletal muscle: veal, 1 to 3 mg/g; beef, 4 to 10 mg/g; and old beef animals, 16 to 20 mg/g. Pork contains 1 to 3 mg/g for young animals of slaughter weight, but may reach 8 to 12 mg/g in old animals. Lamb may vary from 3 to 8 mg/g, but old ewes and rams may reach levels from 12 to 18 mg/g.

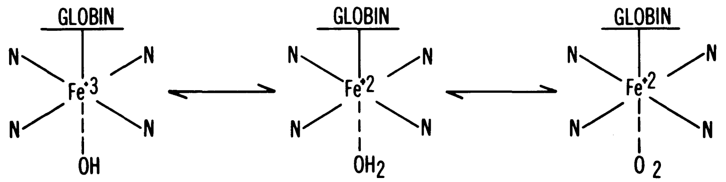
Much of the knowledge about myoglobin was derived from earlier work by blood chemists and physiologists studying the structure and functions of hemoglobin. More recently, however, myoglobin has been extensively studied in its own right by protein chemists, who have detailed its exact amino acid sequence. Although myoglobin and hemoglobin undergo essentially the same reactions, they do have significant differences in structure. Both of these important pigments are molecules composed of a protein, known as globin, complexed to a nonprotein moiety containing iron. Although the globin portion of hemoglobin and myoglobin is similar in structure, the exact amino acid sequence is slightly different. Furthermore, there are slight differences between the globin from different species. The iron-containing fraction of the molecule is known as heme and is composed of two parts—an iron atom and a larger planar ring called porphyrin. The porphyrin is made up of four heterocyclic pyrrole rings linked together by methene bridges. When the hemes and globin are complexed together by the side chains and the iron nucleus, the resulting compounds are either myoglobin or hemoglobin. An essential difference in structure between myoglobin and hemoglobin is that myoglobin complexes only one heme group per molecule, whereas, hemoglobin contains four hemes per molecule. Thus, myoglobin has a molecular weight of 16,000 to 17,000 as compared to approximately 64,000 for hemoglobin.

The central atom does not contribute any electrons but accepts six pairs of electrons from other atoms—five pairs from nitrogen and one pair from oxygen. Four of the nitrogen atoms contributing electrons are in the porphyrin ring, while the other nitrogen atom is from the imidazole group of the histidine molecule in the amino acid chain of globin. The nature of the group attached to the iron atom of the heme at the position shown to be occupied by the OH_2 radical determines the color of the pigment, both of myoglobin and hemoglobin.



Myoglobin

Color of the Pigments. In living tissue, myoglobin and hemoglobin exist in equilibrium between the reduced dull purple-red form, myoglobin and hemoglobin, and the bright red oxygenated form, oxymyoglobin and oxyhemoglobin. Upon death, the oxygen in the tissues is rapidly depleted, leaving the pigment in the dull purple-red form of myoglobin or hemoglobin. The iron can exist in the ferrous (Fe^{2+}) or ferric (Fe^{3+}) forms, or as ionic (unwilling sharer of bonds) or covalent (willing sharer of bonds) bonds. The covalent form is of the greatest importance, since all the bright red pigments of both fresh and cured meat belong to this class. On the other hand, the iron in the dull red-black pigment—oxidized myoglobin and hemoglobin—exists in the ferric form. The nucleus of a myoglobin molecule with changes in the state of the iron and the radical attached to it, effects fresh meat color. The pigment in the oxidized form, metmyoglobin, is an undesirable brown-red and is typical of the color observed on the exposed surface of aged meat. Although the three forms of myoglobin are interconvertible or reversible, changes from metmyoglobin to the other forms are slower and require more favorable conditions.



METMYOGLOBIN (MMb)
BROWNISH-RED TO BLACK

MYOGLOBIN (Mb)
PURPLE-RED

OXYMYOGLOBIN (MbO_2)
BRIGHT CHERRY RED

The pigments containing covalent bonds are characterized spectrally by sharp peaks at 535–545 nm (the green portion of the spectrum) and 575–585 nm (blue), which gives them a bright red color. Oxymyoglobin of fresh meat, nitrosomyoglobin of cured meat and carboxymyoglobin, a combination of carbon monoxide with myoglobin, are characterized by peaks in the green and blue portion of the spectrum, and all are bright red pigments. Myoglobin is characterized by a broad diffuse peak of 555 nm, and thus is dull red in color. In metmyoglobin, the peak is shifted to 505 nm in the blue portion of the spectrum, and has a weaker peak at 627 nm in the red part of the spectrum, the two combining to produce a brown-red color. The absorption spectra of myoglobin, metmyoglobin, and oxymyoglobin are shown in Fig. 3.1. This shows schematically the color at different parts of the spectrum, which, when comined, accounts for the color of the various products.

Myoglobin and hemoglobin can be both oxidized and oxygenated, both resulting from the presence of oxygen. The relative proportion of metmyoglobin and oxymyoglobin depends on the partial oxygen pressure. At low oxygen pressures formation of metmyoglobin is favored, whereas high oxygen pressures favor oxymyoglobin formation. Thus, reduced myoglobin is constantly being both oxygenated and oxidized.

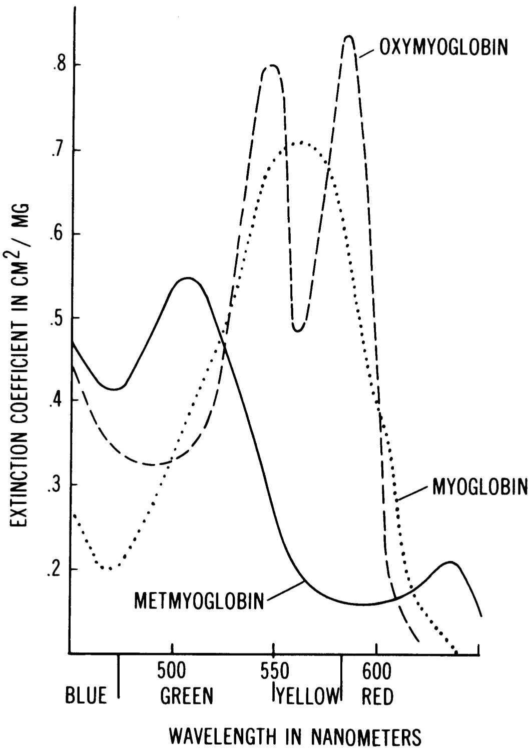


FIG. 3-1. Absorption spectra of myoglobin, oxymyglobin, and metmyglobin from fresh meat in which wave lengths for maximum absorption and the primary color spectrum are displayed.

In living tissues, and to some extent in meat, metmyoglobin is continuously reduced back to myoglobin by the action of the reducing enzymes that are naturally present in the tissues. However, the efficiency of the reducing system gradually decreases and ultimately is depleted following death. Thus there is a gradual build-up of metmyoglobin until it predominates, and the meat color becomes a dull red or brown.

Role of Nitrite and/or Nitrate in Meat Color

Nitrite and/or nitrate are used in curing meat to counteract the undesirable effects of salt on color. Not only is the color of fresh meat protected from degradation, but the pigments react with nitric oxide to produce the stable pigments characteristic of cured meat. These pink pigments are important to the acceptability of most processed meat products.

As indicated, both nitrite and/or nitrate are used in meat curing for color stabilization. The end result is the same in either case, although the pathway for stabilization of color by nitrite is more direct. Nitrite requires one less step in stabilization of color, as shown in the series of reactions below:

$$\text{Nitrate} \xrightarrow[\text{organisms}]{\text{nitrate reducing}} \text{Nitrite} \qquad (1)$$

$$\text{Nitrite} \xrightarrow[\text{absence of light and air}]{\text{favorable conditions}} \underset{\text{nitric oxide}}{\text{NO}} + \underset{\text{water}}{H_2O} \qquad (2)$$

$$\underset{\text{nitric oxide}}{\text{NO}} + \underset{\text{myoglobin}}{\text{Mb}} \xrightarrow[\text{conditions}]{\text{favorable}} \underset{\text{nitric oxide metmyoglobin}}{\text{NOMMb}} \qquad (3)$$

$$\text{NOMMb} \xrightarrow[\text{conditions}]{\text{favorable}} \underset{\text{nitric oxide myoglobin}}{\text{NOMb}} \qquad (4)$$

$$\text{NOMb} + \text{Heat} + \text{Smoke} \rightarrow \underset{\substack{\text{Nitroso-hemochromogen} \\ \text{Stable pink pigment}}}{\text{NO—hemochromogen}} \qquad (5)$$

Since nitrite reacts quicker and less is required for color stabilization, it is being widely used in place of nitrate. Many processors prefer to use a combination of nitrite and nitrate, which gives a source of additional nitric oxide should the nitrite be depleted during curing. They believe the slower release of nitric oxide from nitrate gives them an additional safety factor over nitrite alone. Nevertheless, many highly successful operators use nitrite alone with excellent results. Trends have been toward decreased use of nitrate by the industry.

As shown by the series of reactions, nitric oxide is the active ingredient that combines with meat pigments. Although step 3 has not been proved conclusively, all evidence suggests that the original combination of nitric oxide is with the oxidized pigments, metmyoglobin and methemoglobin. The best proof for this is the fact that the pigments in sausage become characteristically brown after adding the cure, but after heating have the characteristic pink color of cured meat, as shown in step 5. An alternate pathway for production of the stable pink pigment is possible, in which nitric oxide metmyoglobin is not formed. In this case, myoglobin is oxidized to metmyoglobin, which is reduced back to myoglobin before combining to form nitric oxide myoglobin. The end result is the same regardless of the pathway; nitric oxide reacts to produce the desirable and stable pink pigment of cured meat. Any hemoglobin remaining in the meat would undergo essentially the same series of reactions and also give a stable pink pigment.

Figure 3.2 shows how the various forms of myoglobin or hemoglobin fit into the total scheme to produce cured meat pigments, both desirable and undesirable.

CURING METHODS

Although there are a number of methods of curing primal or subprimal cuts of meat, they are all modifications or combinations of two fundamental procedures: (1) dry curing and (2) pickle curing. In dry curing, the curing ingredients—usually salt, sugar, and nitrite and/or nitrate—are added to meat without additional water. In this method,

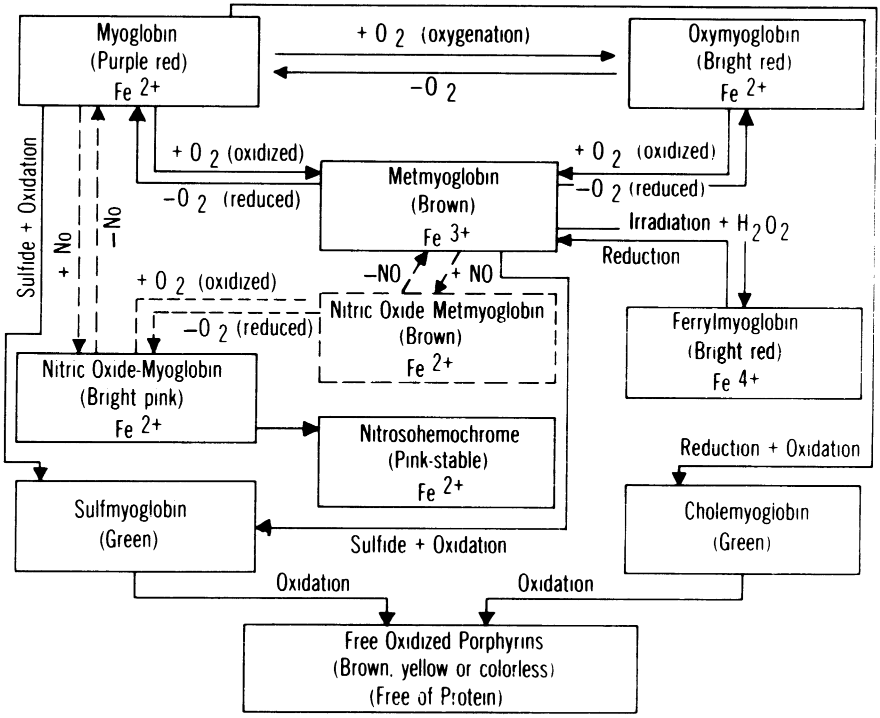


FIG. 3-2. Heme pigments in muscle in relationship to fresh and cured meats. Broken lines indicate reactions and compounds possible but not definitely proven. Sulfmyglobin and cholemyoglobin most frequently occur as a result of bacterial action.

the curing ingredients draw enough moisture from the meat to form a brine, which serves to transport the ingredients into the meat by diffusion. In pickle curing, the ingredients are dissolved in water, which forms a brine that acts in the same general manner as that formed by the natural meat juices and the curing ingredients.

In actual practice, there are several modifications of the dry and pickle curing procedures, which are a result of combining the two methods. For example, one may start with pickle curing and end with dry curing, or vice versa. Thus, for ease of discussion the methods will not be differentiated solely on principles, but by more specific procedures for curing, such as (1) dry salt curing, (2) conventional dry curing, (3) conventional pickle curing, (4) artery pumping, (5) stitch pumping, (6) thermal or hot cures, and (7) curing of speciality products. Each of these curing procedures will be examined in detail.

Dry Salt Cure

The dry salt cure uses salt alone or salt in combination with nitrite and/or nitrate. As indicated earlier, the cure is primarily used in excess and mainly for fatty cuts, such as fat backs, clear plates, jowls, or heavy bellies. The advantages of dry salt curing are (1) it is safe, that is, there is little if any spoilage, and (2) it is easy. Little special care is required to produce dry salt-cured cuts. However, dry salt curing has the disadvantages that the end product is too salty and that color is lost. Color degradation can be easily prevented by adding nitrite and/or nitrate to the cure. Since dry salt curing is used almost exclusively for fatty cuts utilized primarily for seasoning, the salty flavor is actually an advantage in practice. However, there is only a restricted and relatively low-priced market for dry salt-cured products.

Conventional Dry Curing

Dry curing in the conventional manner, which involves salt, nitrite and/or nitrate, and sugar, is sometimes utilized by the industry. However, dry curing is no longer the predominant method of curing, but is used mainly for speciality products, such as dry-cured bacon and Country-cured hams, both of which command a premium on the market. In addition, some artery-pumped hams are rubbed with a dry cure and held for a short period of time. Cuts cured by this procedure cannot be strictly classified as either dry-cured or artery-pumped, but more correctly as combination-cured. Their final properties are, however, altered by the addition of dry cure.

There are a number of modifications of the dry-curing method itself, but the procedure is essentially the same, since water is not added to the cure. These modifications depend mainly on the container utilized in curing. Originally, much of the curing was carried out in barrels, where the brine was formed by withdrawal of natural juices from the meat by the salt. The resulting brine accumulated in the bottom of the barrel. Barrel curing, which is seldom used today, required periodic overhauling with reversal of the order with which the cuts were placed in cure each time. Use of barrels also involves unusually high space requirements, since their shape is not conducive to tight packing and efficient floor space utilization. In addition, use of space between the floor and ceiling is even less efficient.

More efficient use of space in dry curing has been achieved by using built-in shelves, which are often made of hard wood and can be made water-tight. One of the major problems encountered with this type of curing is cleaning and sanitation. Improvements in the method can be obtained by using stainless steel shelves on movable steel racks. The initial investment is high, but ease of cleaning is greatly improved.

Still another modification in the equipment used for dry curing is found in pressure boxes, which are usually made of galvanized iron or stainless steel. The boxes have a lid with a spring to generate pressure. As the pressure in the box is increased, the curing ingredients combine with the meat juices to cover the product with brine. Pressure boxes are most commonly used for bacon, jowls, and other cuts of regular shape.

There are a number of other types of equipment such as wooden and concrete vats and boxes as well as other modifications of the containers described herein. Regardless of the type of equipment, the principle of curing remains unchanged. Furthermore, the advantages and disadvantages of the procedures, although slightly altered, are essentially the same.

The time required for dry curing is usually 2 to 2½ days per pound for hams and shoulders. Bellies are commonly cured about 7 days per inch of thickness. Thus, bacon cured by this method usually requires about 10 to 14 days total time in cure. The cure is applied in two to three stages at the time of overhauling. Bacon cured in pressure boxes does not normally require overhauling, so all the cure is applied at once. The mixture of curing ingredients in dry curing varies somewhat, but a common recipe is 6.0 lb salt, 2.5 lb sugar, and 2.5 oz of nitrate or 0.25 oz nitrite per 100 lb meat, or 1 oz of curing mix per pound meat.

There are three major disadvantages to the dry curing method: (1) high cost due to poor space utilization and the amount of labor required, (2) high inventory due to slowness of curing, and (3) harsh salty flavor of the final product. Even though the salty flavor of dry-cured meat is a disadvantage under average conditions, it can also be an advantage, as is found with Country-cured hams.

The advantages of conventional dry curing are (1) a relatively high-priced specialty product is produced, and (2) cuts are less perishable because of their dryness and firmness.

Conventional dry curing is a useful procedure, but is not likely to regain any large fraction of the total cured meat market. Nevertheless, it is admirably suited to small operations, where attention can be given to the operation and high-quality products are produced. Some consumers prefer dry-cured hams and bacon and are willing to pay a premium for them.

Pickle Cure

The pickle-curing procedure uses the same ingredients as dry curing, except the cure is dissolved in water to form a brine or pickle. The cuts are submerged in the pickle until the cure has completely penetrated the meat. Because the meat is packed tightly in the container, it is usually overhauled and repacked to assure uniform penetration of the brine.

All cuts can be cured by the conventional pickle-curing procedure. It is used largely by locker plant operators and other small processors. Nevertheless, some larger processors still use conventional pickle curing for certain cuts. This method is used to produce corned beef in a large number of plants. In this case, the method is frequently altered by stitch-pumping the larger pieces of meat to speed up the rate of curing. Since the time required for immersion pickle curing is about the same as for the dry cure, this results in an inventory reduction.

The strength of the brine is expressed in terms of degrees brine, which is essentially a measure of its density. A salometer or salinimeter is used to determine strength of the brine, and its strength is adjusted to the desired level. The water used should have a high degree of purity. It is usually cold when added, although it may be necessary to heat or add hot water to get all the curing ingredients into solution. Table 3.2 gives the necessary ingredients required to prepare brines of different salometer readings.

Hams and shoulders are normally cured from 2 to 2½ days per pound, as in dry curing. However, this will depend on the strength of the pickle and temperature of curing. The usual pickles are 60–70°, 70° brine being most common. As indicated earlier, most pickles contain the usual curing ingredients of salt, sugar, and nitrite and/or nitrate. Those containing sugar are sometimes referred to as sweet pickle cures.

The disadvantages, in common with those of dry curing, include (1) poor utilization of space, and (2) slow turnover of meat inventories. Pickle cure usually gives a product with a milder flavor than dry curing and requires less labor. However, space utilization is even poorer, since the pickle must be in a tight container.

Although pickle curing was widely used in the early part of this century, it is now largely used in combination with artery or stitch pumping, followed by either submerging in a cover pickle or by rubbing with dry cure and holding for a short time. However, even combination procedures such as these are declining with emphasis on rapid processing.

Artery Pumping. Artery pumping is said to have been developed by a New Zealand undertaker who decided that the principles utilized in embalming the dead could be applied in curing of meat. Thus, the

TABLE 3.2. Formulas for Preparing Sweet Pickle Cures of Different Salometer Readings

Salt (lb)	Ingredients Sugar (lb)	Nitrite (g)	Cold water[a] (gal)	(lb)	Salometer reading at 40°F[b]
10	3	28	4	33⅓	95°
9	3	28	4	33⅓	90°
10	3	33	5	41⅔	85°
8	3	28	4	33⅓	80°
8	3	33	5	41⅔	75°
6	3	28	4	33⅓	70°
7	3	33	5	41⅔	65°
6	3	33	5	41⅔	60°

[a] Weight of water—hot = 8.016/gal, cold = 8.3316 gal.
[b] Water temperature must be adjusted to 40°F to obtain an accurate salometer value.

method makes use of pumping a pickle or brine into the cuts through the arterial system. Since the conventional cutting procedures used to disassemble carcasses do not maintain the intact arterial system, the procedure is almost entirely limited to curing hams and, to a lesser extent, picnics. Figure 3.3 shows a modern artery cure pumping operation.

The needle is usually inserted in front of the branch in the femoral artery so that the pickle goes into the entire ham. Some operators insert pickle into each branch and claim more uniformity in cure, although the operation is more time-consuming. The pumping schedule commonly calls for adding 8–10% by weight of the pump pickle. In some cases, one stitch pump (about 3 oz of pickle) is injected into the cushion. Some operators believe this minimizes undercuring and deep seated spoilage.

The curing ingredients are essentially the same as for dry curing, except the brine is dissolved in water to make a pickle. In addition to water, the pickle contains salt, sugar, and nitrite and/or nitrate. It is a common practice to also use phosphates to aid in water retention and increase yields. Nitrite has largely replaced nitrate, since the hams are frequently held for very short periods before smoking, which requires rapid color development.

Some 25 to 30 years ago, hams were pumped and then placed in

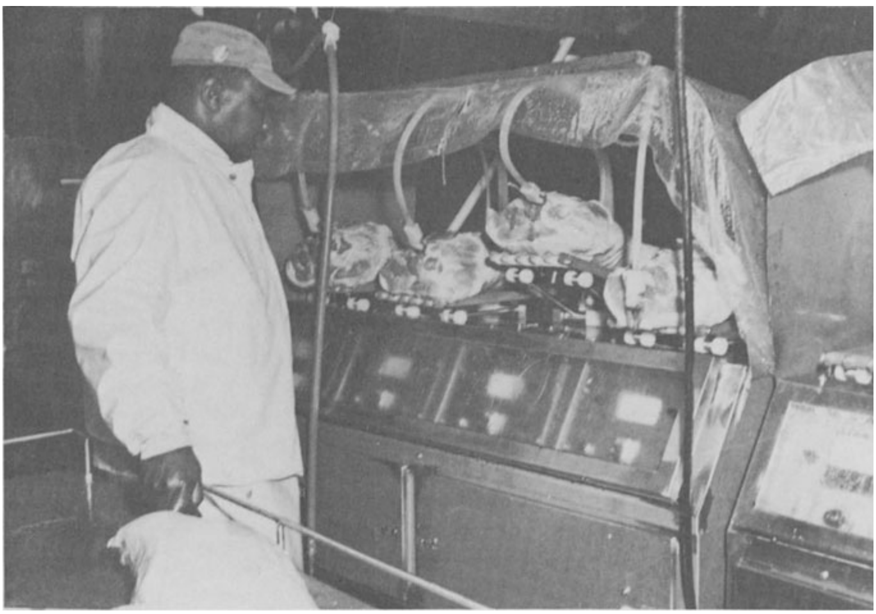


FIG. 3-3. Artery cure pumping operation. Courtesy of the National Provisioner, Chicago, Illinois.

either brine or dry cure and held for 7 to 14 days before smoking. At present, the holding time before smoking is much shorter, many processors pumping the hams and holding for only a few hours. Some processors go directly into the smokehouse after pumping, but the majority hold them for 1 to 3 days. The use of dry cure is sometimes helpful to bring yields within legal limits. Cover pickles are also used during the holding period to complete the curing process.

The pump pickle is usually a 65–80° brine, 65° being the most common under commercial conditions. Sugar is usually added at a level of 20–30 lb per 100 gal brine; cane sugar is used most commonly. Nitrite is usually utilized instead of nitrate, and at a level of 150 ppm, or 1.5 oz per 100 gal brine. If cover pickles are used, strength of the brine is usually 55–60°.

The major advantage of artery pumping is the speed of curing and the resulting reduction of inventories through more rapid turnover. A second advantage is the relatively high yield, which is usually further improved by use of alkaline phosphates. The major disadvantages are (1) it is largely limited to curing of hams and picnics and cannot be readily used for other products; (2) special care is required in cutting to maintain the artery intact; (3) hams cured by this procedure are perishable and require refrigeration. This is not a serious disadvantage because the majority of consumers prefer the mild-cured product.

Single-Needle Stitch Pumping. Stitch pumping utilizes a needle having several openings, so it can be adapted to a variety of cuts. It does not depend on the arterial system. Usually, the operator makes three to five stitches per cut of meat, delivering about 3 oz of brine per injection. However, the total amount of pickle injected is based on adding a given weight of pickle, depending on its strength. Generally, 10% by weight of a 65° pickle containing 150 ppm nitrite plus alkaline phosphate is utilized.

Stitch pumping gives a somewhat wetter product than artery pumping and requires special care to produce a good-quality product because the brine often accumulates at the injection site. As a consequence, a longer time is required for cure diffusion by stitch pumping.

Many processors use artery pumping for hams and stitch pumping for curing picnics, shoulders, bellies, and other miscellaneous cuts. The amount of meat cured by stitch pumping and artery pumping has increased greatly in the last 30 years.

Multiple-Needle Stitch Pumping. The regularity in shape and freedom from bone makes bellies ideally suited for curing by injection pumping. Hams, both bone-in and boneless, are also injection-cured. Mechanization of the pumping operation using the same principles as utilized in stitch pumping provided the real impetus for change. The results have been greatly reduced labor costs and time required for production. Pickle injection has also increased yields, all of which have contributed to lower production costs. The quality of the final product is not as high as for dry-cured bacon, since the flavor is less desirable and cooking shrinkage is greater. Nevertheless, it has been estimated that about 80% of U.S. bacon production is produced by injection curing.

There are several models of machines for injecting the cure into bellies and hams. Most injection equipment contains a series of off-set needles. Pickle is pumped until the desired weight is obtained. Since the pickle enters through a large number of needles spaced relatively close together, the distribution of pickle is excellent. This results in rapid curing. Figure 3.4 shows a stitch pumping machine.

Thermal or Hot Cures

In recent years, several groups have experimented with hot cures, which can be either hot dry cures or hot pickles. The hot cures speed up the rate of curing and allow acceleration of the entire processing operation. To achieve maximum advantages from heating, the curing ingredients must be distributed into the tissues rapidly before the cure becomes cold.

Hot pickle cures can best be applied by artery pumping or stitch pumping. There are advantages in raising the temperature of the products either before or immediately after injection. This can best be

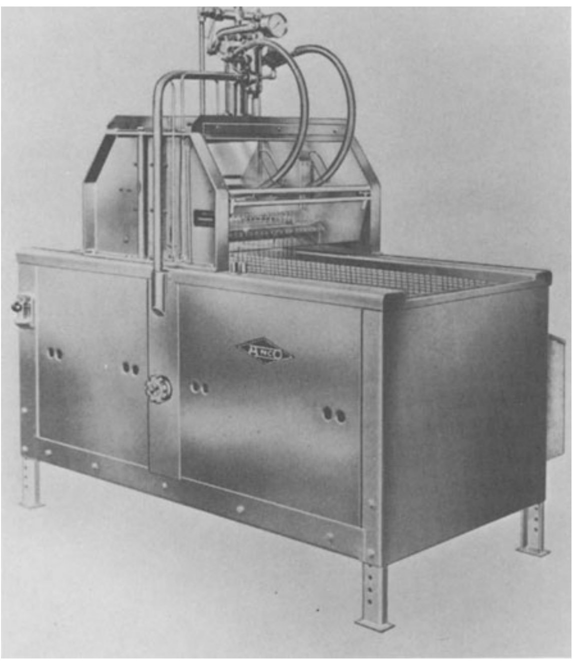


FIG. 3-4. Injection pump. Courtesy of Allbright-Nell Co., Chicago, Illinois.

achieved by placing them in the heated pickle. Best results with the hot-pickle method have been achieved using a 70° pickle at a temperature of 135°–140°F. Hams should not be held in the hot pickle for periods longer than 1 hr, while 30 min is adequate. Following the heating period, the hams can go directly into the smokehouse. Holding overnight before smoking gives the best results.

Hot dry cure is not well adapted to large cuts but can be used to produce dry-cured bacon. One machine utilizes a series of off-set needles similar to those used for injection of brine into bellies, except they are used solely for making perforations in the tissues. The hot dry cure is then applied to the perforated bellies and rapidly penetrates the tissues; 3–5 lb of cure are recommended per 100 lb of bellies. A temperature of curing between 48° and 50°F is recommended, with 3 to 5 days total curing time. This curing procedure is patented. The advantages claimed for hot dry curing are (1) rapid curing with reduction of inventory, (2) greater amounts of smoke flavor, as smoke also penetrates the perforations, (3) increased yields over dry curing, although lower than injection-cured bellies, (4) absence of pickle pockets, and (5) improved flavor. The disadvantages include problems in heating and applying the cure and the reduced yields as compared to injection curing. Also, hot dry curing is adapted only to relatively thin cuts.

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4

Smoking

It seems probable that nomadic man first discovered the preservative action and the desirable flavor imparted to meat that was hung near his fire. Regardless of its origin, smoking, like curing, of meat has been practiced since the beginning of recorded history. Curing and smoking of meat are closely interrelated and are often practiced together, i.e., cured meat is commonly smoked, and vice versa. Smoking of meat is also difficult to separate from cooking, since heat has traditionally been applied at the same time as smoke. However, the application of smoke and heat together are not necessarily closely allied, as smoke and heat can be applied either together or separately. Thus there are both hot and cold smoking of meat; however, even cold smoking usually requires some increase in temperature.

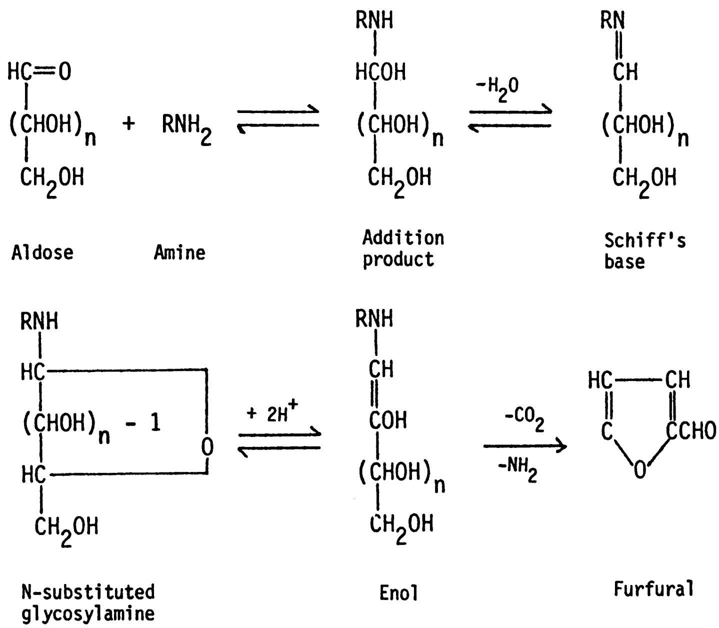
Smoking, like curing, has a preservative effect on meat. With mechanical refrigeration, the importance of preservation has declined. Today, mild-smoked, cured products are often eaten to add variety and attractiveness to the diet. Consequently, smoke serves primarily to provide variation in flavor. The highly smoked products of earlier times have largely disappeared, although consumers in some countries still prefer highly smoked meat products. Examples of this are commonly seen in northern European countries and in Iceland, where heavily smoked meat products are still preferred.

PURPOSES OF SMOKING

The primary purposes of smoking meat are (1) development of flavor, (2) preservation, (3) creation of new products, (4) development of color, and (5) protection from oxidation. Smoking of meat and creation of new flavors has developed an entirely different group of meat products. Formerly, many of these products were heavily smoked; but the trend is now toward less smoke flavor, many commercial products containing only a small trace of it. In fact, it is conceivable that smoke could be completely eliminated without any serious effect on the acceptability of a great many products.

Smoking and cooking, which are generally carried out together, are also involved in development of color. This is true for the development of cured meat color, which is stabilized by heating. Furthermore, the brown color developed on the surface of many processed meat products is also enhanced by smoking.

The browning or the Maillard reaction (after the French chemist who first described browning) is responsible for development of the characteristic brown color on the surface of smoked products. Although the exact mechanism of browning is not fully known, it involves reaction of the free amino groups from proteins or other nitrogenous compounds with the carbonyl groups from sugars and other carbohydrates. Since carbonyls are major components of wood smoke, they play a major role in browning during smoking of meat. A proposed mechanism for the development of browning is outlined below:



The first step in nonenzymatic browning is aldol condensation, which is followed by the Schiff's base formation and ultimately by Amadori rearrangement. The final step is Strecker degradation, which is not completely understood. The final reaction results in formation of furfurals or hydroxymethyl furfurals, which are brown or black in color.

The reaction is not fully understood and involves a number of intermediate steps, which have not been fully elucidated. The important steps in the reaction then involve aldol condensation, Schiff's base formation, and Amadori rearrangement, with ultimate production of brown or black furfural compounds. These reactions occur only in neutral or acidic conditions with formation of a Schiff's base ring compound of hydroxymethyl furfural or furfural. Although there are other possible pathways for development of brown color in smoked meat, the mechanism discussed here seems to be the most logical in view of conditions present in the product. Obviously, only a few of the total reactive carbonyls and free amino groups actually participate in formation of the furfural compounds, which give the brown color to smoked meat.

One of the most important properties of smoke is its effect on the bacterial population. Smoking of bacon has been shown to reduce the number of surface bacteria greatly and to extend its storage life. This is due to the bactericidal and bacteriostatic properties of smoke. These properties are attributable to certain components in the smoke, such as phenols and acids, which will be discussed later. Unquestionably, removal of moisture from the surface of meat during smoking also retards and reduces bacterial growth.

Smoke is also known to have a definite influence on the development of rancidity by virtue of its antioxidant activity. This extends the shelf life of smoked meat products and helps to account for their desirability. The antioxidant activity of smoke will be discussed in greater detail under the specific components found in smoke that contribute this important property.

COMPOSITION OF SMOKE

Over 300 different compounds have been isolated from wood smoke. This does not necessarily mean that all these compounds occur in smoked meat, as the temperature of combustion, conditions in the combustion chamber, oxidative changes in the compounds formed and many other factors influence smoke composition. Furthermore, many of the compounds present in smoke are of little importance from the standpoint of either flavor or preservation.

The chemical components most commonly found in wood smoke include phenols, organic acids, alcohols, carbonyls, hydrocarbons, and some gaseous components, such as carbon dioxide (CO_2), carbon monoxide (CO), oxygen (O_2), nitrogen (N_2), and nitrous oxide (N_2O).

Phenols

About 20 different phenols have been isolated from wood smoke and identified. Among them are guaiacol, 4-methylguaiacol, phenol, 4-ethylguaiacol, *o*-cresol, *m*-cresol, *p*-cresol, 4-propylguaiacol, eugenol (4-allylguaiacol), 4-vinylguaiacol, vanillin, 2,6-dimethoxyphenol, 2,6-dimethoxy-4-methylphenol, 2,6-dimethoxy-4-propylphenol, and 2,6-dimethoxy-4-ethylphenol. Although other phenols have been isolated from wood smoke distillates, they are apparently present in smaller amounts and are probably less important from the standpoint of their contributions. The exact importance of individual phenols in wood smoke is not known, but the somewhat variable composition reported by different investigators suggests the individual components are not as important as a number of different phenols. The effect of altering smoking conditions on the total phenol content will be discussed later.

Phenols appear to play a threefold role in the smoking of meats and other foods: (1) they act as antioxidants, (2) they contribute to the color and flavor of smoked products, and (3) they have a bacteriostatic effect that contributes to preservation. The role of phenols in preventing oxidative changes in smoked meat is most important. Undoubtedly, the antioxidant activity of smoke is one of its most important attributes in smoked foods. Most of the antioxidant properties of wood smoke are due to the phenols with high boiling points, especially 2,6-dimethoxyphenol, 2,6-dimethoxy-4-methylphenol and 2,6-dimethoxy-4-ethylphenol. On the other hand, low-boiling phenols have only weak antioxidant activity. Smoke produced by smoldering as is commonly used by the meat industry possesses strong antioxidative properties. The particle phase of wood smoke but not the vapor phase has been shown to enhance the antioxidant properties of smoked foods.

Color and flavor are the important sensory attributes that contribute to the desirability of smoked meats. Color development is caused by the interaction of the carbonyls in the vapor phase of the smoke with amino groups on the surface of the foods. Phenols also contribute to color development. The actual color formation is believed to be due to the Maillard reaction or some similar reactions as discussed earlier. Maximum color formation is directly related to smoke concentration, temperature, and the moisture content at the surface of the products, with 12–15% of moisture at the exterior surface of meat resulting in maximum color development. Thus, some surface drying is necessary for good color formation during the smoking of meats.

The characteristic flavor of smoked meats is primarily due to the phenolic compounds in the vapor phase. The phenols that are mainly responsible for the flavor and aroma of smoked meats are guaiacol, 4-methyl-guaiacol, 2,6-dimethoxyphenol and syringol, with the first three compounds contributing most of the flavor and the latter being the primary contributor to aroma. Vanillic acid appears to be responsible for a sweet, mellow note in the aroma of wood smoke. Other acids and carbonyls probably contribute to the flavor of smoked meats; however, the flavor and aroma of whole smoke appears to be due to a more complex mixture.

The bactericidal action of smoking meat is due to the combined effects of heating, drying, and the chemical components in the smoke. When present on the surface of the meat, smoke components such as acetic acid, formaldehyde, and creosote prevent microbial growth. The phenols are known to possess strong bacteriostatic activity; in fact this has led to the use of the phenol coefficient as a standard method for expressing the effectiveness of different germicides relative to phenol. The high boiling point phenols have the most bactericidal activity. The bacteriostatic effect is primarily on the surface, however, since the amount of smoke penetration is limited.

Since smoke is largely concentrated on the surface of smoked-meat products, the total phenol concentration at varying depths has sometimes been used to express the depth of penetration and concentration of smoke. However, total phenol concentration is not always equivalent because the individual phenols are not equal in either color or flavor. Thus, the use of total phenols to measure the smoked flavor of meat is not necessarily closely related to sensory evaluation.

Alcohols

A wide variety of alcohols are found in wood smoke. The most common and simplest of these is methanol or wood alcohol, so-called because it is one of the main products obtained on destructive distillation of wood. Although primary, secondary, and tertiary alcohols are all found in smoke, they are frequently oxidized to form their corresponding acids.

The role of alcohols in wood smoke appears to be primarily that of a carrier for the other volatile components. Alcohols do not seem to play any major part as contributors to flavor or aroma, although they may exert a minor bacteriocidal effect. Thus alcohols are probably one of the least important classes of components in smoke.

Organic Acids

Simple organic acids ranging from 1 to 10 carbons are components of whole smoke. Only 1- to 4-carbon acids are commonly found in the vapor phase of smoke, whereas longer chain 5- to 10-carbon acids are in the particle phase of whole smoke. Thus formic, acetic, propionic, butyric, and isobutyric acids contribute to the vapor phase of smoke, whereas valeric, isovaleric, caproic, heptylic, caprylic, nonylic, and capric acids are located in the particle phase.

Organic acids have little or no direct influence on the flavor of smoked products. They also appear to have only a minor preservative action, which occurs as the result of greater acidity on the surface of smoked meat.

Experience with artificial smoke preparations has shown that acid does, however, play an important part in coagulation of the surface proteins of smoked meat. Coagulation is essential in developing the outside covering on skinless frankfurters. Hence, acids serve a most important function in peelability of skinless frankfurters and similar skinless sausages. Coagulation of the surface proteins is enhanced by heat, but acids also seem to be essential for good skin formation. Although this can be achieved rapidly by dipping or spraying with acid solutions, the same final effect on skin formation is obtained more slowly by smoking. The volatile or steam-distillable acids are apparently the most useful fraction in skin formation.

Carbonyls

A large number of carbonyl compounds contribute to smoke. Similar to organic acids, they occur in the steam-distillable fraction and also in the particle phase of smoke. Well over 20 compounds have been identified: 2-pentanone, valeraldehyde, 2-butanone, butanal, acetone, propanal, crotonaldehyde, ethanal, isovaleraldehyde, acrolein, isobutyraldehyde, diacetyl, 3-methyl-2-butanone, pinacolene, 4-methyl-3-pentatone, α-methyl-valeraldehyde, tiglic aldehyde, 3-hexanone, 2-hexanone, 5-methyl furfural, methyl vinyl ketone, furfural, methacryaldehyde, methyl glyoxal, and others.

Although the largest proportion of the carbonyls are nonsteam-distillable, the steam-distillable fraction has a more characteristic smoke aroma and contains all the color from the carbonyl compounds. Thus, short-chained simple compounds appear to be most important to smoke color, flavor, and aroma.

Many of the same carbonyls found in smoke have been isolated from a wide variety of foods. This suggests that either certain carbonyl compounds contribute to smoke flavor and aroma, or more probably, the level of carbonyls in smoke is much higher and thus imparts the characteristic aroma and flavor to smoked products. Regardless of the mechanims or cause, smoke flavor and color seem to be largely due to the steam-distillable fraction of smoke.

Hydrocarbons

A number of polycylic hydrocarbons have been isolated from smoked foods. These include benz[*a*]anthracene, dibenz[*a,h*]anthracene, benz[*a*]pyrene, benz[*e*]pyrene, benxo[*g,h,i*]perylene, pyrene, and 4-methyl pyrene. At least two of these compounds, benz[*a*]pyrene and dibenz[*a,h*]anthracene, are recognized as being carcinogens. Both benz[*a*]pyrene and dibenz[*a,h*]anthracene have been demonstrated to be carcinogenic in laboratory animals. Both have also been implicated in human cancer because Baltic Sea fishermen and Icelanders, who consume large quantities of smoked fish, have a high incidence of cancer compared to other populations.

Although the content of benz[*a*]pyrene and dibenz[*a,h*]anthracene is relatively low in most smoked foods, larger proportions have been found in smoked trout (2.1 mg/1,000 g wet weight) and mutton (1.3 mg/1,000 g wet weight). The concentration of benz[*a*]pyrene in other smoked fish amounts to only 0.5 mg for cod and 0.3 mg for red fish per 1,000 g of tissue. Although much higher levels of other polycylic hydrocarbons have been found in smoked foods, none of these has been demonstrated to be carcinogens.

Fortunately, the polycylic hydrocarbons do not appear to impart important preservative or organoleptic properties to smoked meats. Studies have shown that these compounds are removed in the particulate phase of smoke. Several liquid smoke preparations have been subjected to analysis and have been found to be free of benz[*a*]pyrene and dibenz[*a,h*]anthracene. Thus, smoke fractions can be prepared that are free of the undesirable hydrocarbons found in whole smoke.

Gases

The significance of the gases released in smoke is not fully understood. Most of them probably are unimportant in their contribution to smoke. Both CO_2 and CO are readily absorbed on the surface of fresh meat, where they may react to produce the bright red pigments, carboxymyoglobin and carbonmonoxide-myoglobin, respectively. However, there is no evidence that these reactions occur during smoking of meat. Oxygen can also combine with myoglobin to form either oxymyoglobin or metmyoglobin. Again, there is little evidence that either of these reactions take place during smoking of foods.

The gaseous component in smoke that is probably of the greatest significance is nitrous oxide, which has been linked to formation of nitrosamines and nitrites in smoked foods. Nitrosamines can form either directly by interaction of nitrous oxide with the secondary amines in the food or indirectly by formation of nitrites, which may then react with secondary amines to form nitrosamines. The pH of meat being in the acid range may not favor the direct reaction of nitrous oxide with secondary amines to form *N*-nitrosamines, since this reaction occurs best under alkaline conditions.

ACTION OF SMOKE ON NUTRITIVE VALUE

The phenols and polyphenols tend to react with the sulfhydryl groups of the proteins, whereas, the carbonyl groups from smoke react with the amino groups. Both of these reactions can decrease the nutritional value of the proteins by causing a loss in the available amino acids, especially of lysine.

Smoking can cause some destruction of thiamine, but has little effect on niacin and riboflavin. The antioxidant properties of wood smoke should help stabilize the fat-soluble vitamins and would also be expected to prevent surface oxidation of smoked meat products. Thus, smoking of meat can also have some nutritional advantages.

PRODUCTION OF SMOKE

Wood consists of 40–60% cellulose, 20–30% hemicellulose, and 20–30% lignin. During thermal decomposition of wood or wood sawdust, a temperature gradient temporarily exists between the outer surface and the inner core. The outer surface is being oxidized and the inner surface is being dehydrated before it can be oxidized. The temperature of the outer surface is slightly above 212°F during the dehydration process. Carbon monoxide, carbon dioxide, and some volatile short-chain organic acids, such as acetic, are being released during the dehydration or distillation process. When the internal moisture level in the center of the sawdust approaches zero, the temperature rapidly rises to 570°–750°F. Once the temperature falls within this range, thermal decomposition occurs and smoke is given off. Actually, most of the changes in wood of any consequence to smoke generation occur between 390° and 750°F. In the temperature range 390° to 500°F, the release of gases and a sharp increase in the amount of volatile acids is evident. Between 500° and 590°F, pyroligneous liquor and some tars are produced. As the temperature reaches 590°F or above, lignin is decomposed, yielding phenol and its derivatives.

Under normal smoking conditions, the entire range of temperatures is encountered, varying from 212° to 750°F or higher. This results in production of more than 300 components that have been isolated from whole wood smoke. The complexity of smoke composition is further influenced by the oxidative changes that result from introduction of oxygen during smoking. When the amount of air is limited severely, the resulting smoke is dark in appearance and contains relatively large amounts of carboxylic acids. Such smoke is generally undesirable for smoking of meat. Thus, the design of a smoke generator should provide for adequate air during combustion.

Although combustion and oxidation occur simultaneously, it is possible to separate and study the influence of generating conditions on the quantity and quality of smoke. The quantity of acids and phenols increases as available oxygen increases, and production reaches a maximum when approximately eight times the amount of oxygen required for complete oxidation is provided. Decomposition of lignin and production of phenols is greatest above 590°F, whereas acids are produced in larger quantities at lower temperatures; hence, as the combustion temperature is increased above 570°F, the ratio of acids to phenols is reduced. Thus, there is a marked difference in smoke produced at temperatures less than 570°F compared to that generated at over 570°F. Temperatures favoring phenol production also oxidize them to other products, some of which adversely affect the aroma and flavor of smoke.

The best quality smoke is produced at a combustion temperature of 650°–750°F and at an oxidation temperature of 390°–480°F. Under actual operating conditions, it is not possible to separate the oxidation and combustion processes, since smoke generation is exothermic. However, it is possible to design smoking equipment that will give better control of smoke generation. A sawdust fluidizer has been developed in

Europe, which gives closer control of combustion temperature and rate of oxidation.

Although combustion temperatures of 750°F are desirable for maximum production of phenols, this high temperature also favors formation of benz[*a*]pyrene and other polycylic hydrocarbons. To minimize the production of carcinogenic substances, a more practical combustion temperature of 650°F appears to be a reasonable compromise.

THE NATURE OF SMOKE

Although smoke at the point of generation exists in a gaseous state, it rapidly partitions into a vapor and particle state. The vapor phase contains the more volatile components and is largely responsible for the characteristic flavor and aroma of smoke. Experiments making use of electrostatic precipitation of the particle phase have shown that 95% of the smoke flavor of meat products comes from the vapor stage. Furthermore, removal of the particle phase by precipitation also greatly reduces the content of tars and polycylic hydrocarbons, all of which are undesirable in smoke. This probably accounts for the failure of electrostatic smoking, which was once considered a promising method, but has since been abandoned by the industry.

As soon as the smoke is generated, numerous reactions and condensations occur. Aldehydes and phenols condense to form resins, which represent about 50% of the smoke components and are believed to provide most of the color in smoked meats. Polyphenols are also formed by condensation, and there are probably many more interactions and condensations. Obviously, condensation products may possess different properties than the original smoke components. Such changes could affect smoke desirability, uptake, and also penetration through sausage casings.

DEPOSITION OF SMOKE ON MEATS

The amount and rate of smoke deposition is influenced by (1) smoke density, (2) smokehouse air velocity, (3) smokehouse relative humidity, and (4) the surface of the product being smoked. The relation of smoke density to rate of deposition is obvious, since the denser the smoke the greater the smoke uptake. The air velocity in the house also facilitates uptake, since more rapid movement brings more smoke into contact with the meat surface. However, as high air velocity makes it more difficult to maintain high density, density and air velocity tend to be in opposition to each other. In actual practice, there is usually a compromise between the two, with enough air movement to achieve good contact with the product being smoked, but not rapid enough to greatly reduce density. Relative humidity can influence not only the rate of deposition but also the nature of the deposit. High humidity favors smoke deposition but limits color development. The moisture or lack of moisture on the product surface also influences smoke uptake; a moist surface favors uptake and a dry surface retards it.

In practice, smoke uptake and color development must be balanced to produce the desired product. Since some products must be dry and others more moist, the smoking process must be altered to produce the appropriate end product. Furthermore, smoking is frequently also combined with cooking during production of many sausage and smoked-meat products, smoking being a secondary aim.

METHODS OF SMOKING

Smoking as originally practiced was a relatively simple process, but as it became industrialized, it became more complex but also more reproducible. Old-style country smokehouses, such as those used for the smoking of Lebanon bologna, shown in Fig. 4.1, had little or no

FIG. 4-1. Old style country smokehouse. Courtesy of The National Provisioner, Chicago, Illinois.

control of temperature, humidity, or rate of combustion; these have largely been replaced with sophisticated equipment in which it is possible to regulate closely not only these three important factors but also smoke density. It is not the purpose of this discussion to describe modern smoking equipment in specific terms, but only in a general way.

Basically, there are three types of smokehouses, namely (1) natural air circulation, (2) air-conditioned or forced air, and (3) continuous. There are, in addition, many modifications of the three types. The first type is designed so that natural ventilation will occur. Regulation of the volume of air is controlled by the opening or closing of a series of dampers, thus providing natural circulation. The fire pit may be designed to use either logs, sawdust, or a combination of the two. Supplemental heat may be supplied by steam coils or gas. Sprinklers are usually installed to extinguish incipient fires.

A modification of the natural air smokehouse that has found some favor by the industry is the revolving smokehouse. It consists of an endless chain, to which the meat is attached. The endless chain keeps the meat in continuous motion. This system is particularly useful where curing is carried out on one level and smoking on another, since it eliminates the need for an elevator. Although the revolving smokehouse is well adapted to old multilevel packing plants, the higher labor requirements associated with this type of smoking have placed them at a marked disadvantage. A revolving smokehouse is shown in Fig. 4.2.

FIG. 4-2. Revolving smokehouse. Courtesy of The National Provisioner, Chicago, Illinois.

Air-conditioned or forced-ventilation smokehouses, as shown in Fig. 4.3, have largely replaced the natural air type. They are particularly useful where cooking or partial cooking is done and permit much more precise control of smoking. Even more important than the smoking process is control of the temperature for cooking and the resultant control of shrinkage. Air circulation is controlled by a fan, so the air can be recirculated, exhausted, or a portion of the air exhausted and part recirculated. Thus this type smokehouse gives uniform air movement and good control of temperature. Forced-air smokehouses usually control not only air or smoke velocity, but usually also regulate humidity.

The continuous smokehouse comprises part of the continuous processing system and was developed specifically for frankfurter production. One type is shown in Fig. 4.4. The system usually produces about 1.5 to 5 tons of finished product per hour. It has the advantage of occupying less space than conventional smokehouses of similar capacity and also has a much lower labor requirement per unit of finished product. The continuous smoking system also permits better control of shrinkage. The smoking section of the continuous processing line must be equipped with supplemental smoke generators to allow cleaning and repair without shutting down the line.

The continuous smoking system offers some major advantages in

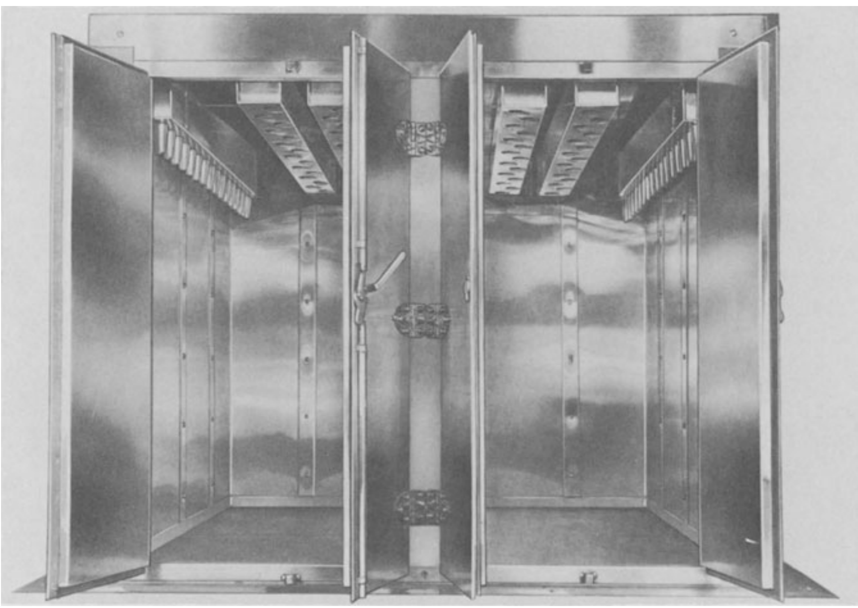


FIG. 4-3. Forced air smokehouse. Courtesy of The National Provisioner, Chicago, Illinois.

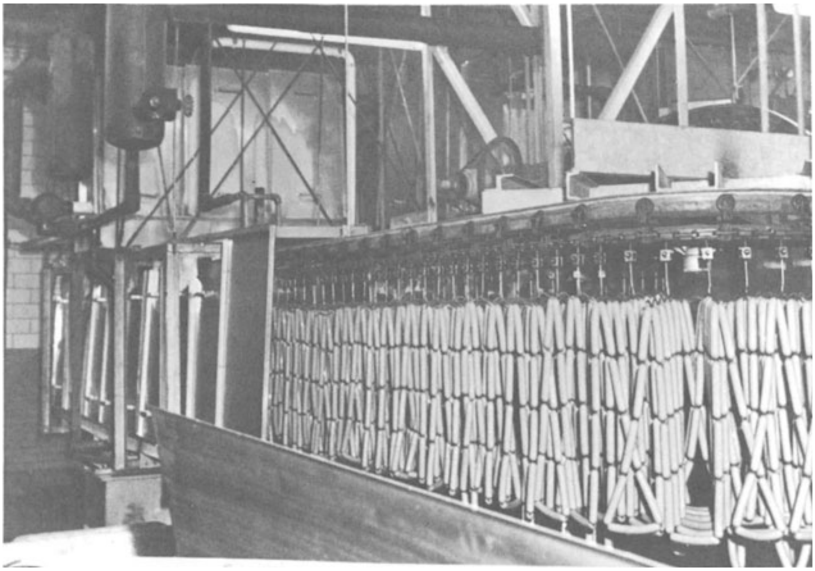


FIG. 4-4. Continuous smokehouse. Courtesy of The National Provisioner, Chicago, Illinois.

space saving, speed of processing, labor savings, and allows more specific control of processing time, temperature, and relative humidity. However, the large capital investment and high output limit its usefulness.

TYPES OF FUEL

A variety of fuels have been used for smoking of meat, varying from animal dung (in some countries), to corn cobs, through a variety of soft and hard woods. Since there is considerable variation in the composition of various fuels, the components of smoke vary widely. The reactions involved in production of smoke will depend largely on individual fuels and their composition.

As already indicated, wood is composed of cellulose, hemicellulose, and lignin. When heated, cellulose breaks down to form 1,6-anhydroglucose, apparently by first forming glucose and then by dehydration to 1,6-anhydroglucose. Further heating decomposes 1,6-anhydroglucose into such products as acetic acid, phenols, water, and acetone. Hemicellulose is composed of pentosans and upon thermal decomposition produces furans, furfurals, and acids. The pentosans yield a larger quantity of acids than either cellulose or lignin. Furthermore, pentosans are the least heat-stable component in wood and tend to break down first. As mentioned previously, phenolic compounds are the major products of thermal degradation of lignin. Thermal decomposition of lignin also yields methanol, acetone, a variety of simple organic acids, a number of phenols, and a quantity of nonsteam-volatile components. There is also some evidence that both lignin and cellulose produce polycyclic hydrocarbons at high generation temperatures, particularly in the absence of oxygen.

Originally, smoldering cord wood was used as the fuel for producing smoke. However, it was soon learned that green or partially cured woods gave better control of temperature and a denser or heavier smoke. Today, most commercial smoking operations have abandoned cord wood and gone to sawdust, which is easier to utilize and gives a greater volume of smoke. This has resulted in designing of special smoke generation units using sawdust and forced air to accelerate smoke production. The sawdust is often wet down and used damp to control burning and density of smoke. Figure 4.5 shows a bank of three modern smoke generators.

A special friction generator, in which a spinning disk is used to generate smoke when in contact with a solid wood block, has been used extensively for experimental studies. Friction-burning has produced some organoleptic differences in comparison to smoke from smoldering sawdust. Friction-generated smoke has more carbonyls and acids but a lower level of phenols than sawdust smoke. Water-washing of friction-generated smoke improves its flavor and odor.

Hardwoods are best for smoking, and softwoods such as pine have been largely avoided. However, liquid smoke has been produced satisfactorily from both hard and soft woods. Hickory has come to be the standard of excellence for smoking meat, but it is almost impossible to obtain good hickory sawdust in its pure form. Therefore, sawdust is most often a mixture of hardwoods.

COOKING DURING SMOKING

Cooking is often done simultaneously with smoking of meat. In fact, cooking is often more important than smoking in meat processing. Cooking requires careful control of the smoking and heating process to give best results. It is almost always carried out on cuts such as hams, picnics, and butts and on a great many processed sausage items. Cooking is accomplished by either steam or gas heat. Usually the humidity is increased during the early phases of cooking, since heat transfer is more efficient at a high humidity.

The final temperature reached depends on the product and is expressed as the internal temperature achieved in the finished product. Smoked hams, butts, and picnics usually receive the minimum heat treatment necessary to destroy the trichinae organism. Federal regulations specify this as a final internal temperature of 137°F, but in practice most packers use 140°F. This allows some margin of safety.

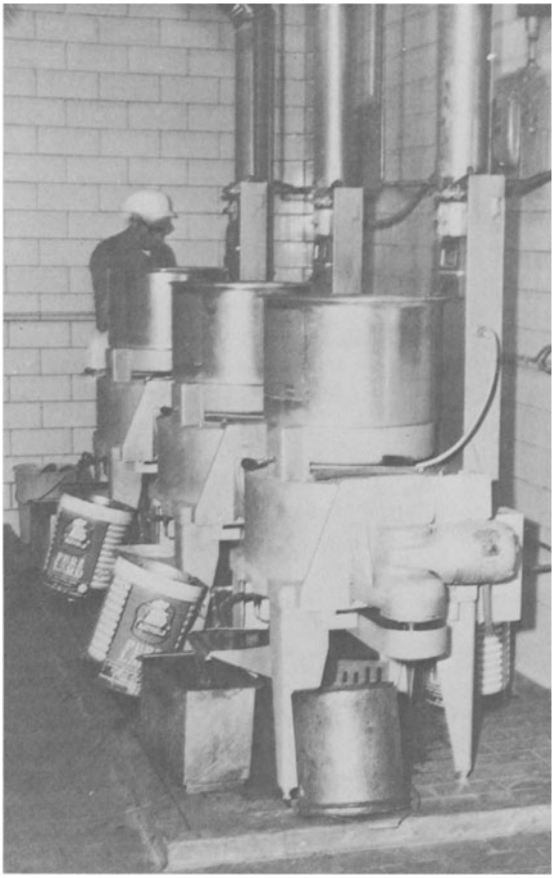


FIG. 4-5. Smoke generators. Courtesy of The National Provisioner, Chicago, Illinois.

Federal regulations specify that fully cooked processed meat items must attain a minimum internal temperature of 148°F. A common internal temperature of frankfurters, bologna, and loaf items is about 155°F, while fully cooked hams are usually cooked to an internal temperature of 150° to 155°F.

Careful control of the entire cooking and smoking cycle results in higher yields. The humidity level, which is generally controlled in air-conditioned smokehouses by the gradient between the wet and dry bulb temperature, is particularly important in controlling final conditions. The exact schedule of temperatures, humidities, and times are worked out in detail by experimentation. Then the operator need only follow the schedule. A continuous recording of times, temperatures, and of wet and dry bulb readings should be made for each batch of product processed. Such information is extremely helpful in trouble shooting. Frequently, problems encountered in processing can be quickly located by examination of cooking schedules.

LIQUID SMOKE PREPARATIONS

Several liquid smoke preparations are available on the market. Liquid smoke is used by some processors and has several advantages over natural wood smoke. First, it does not require the installation of a smoke generator, which usually requires a major financial outlay. Second, the process is more repeatable, as the composition of liquid smoke is more constant. Third, liquid smoke can be prepared with the particle phase removed, and thereby possible problems from carcinogens can be alleviated. Fourth, liquid smoke application creates little atmospheric pollution and can be applied easily, even in plants located in densely populated areas. And fifth, liquid smoke application is faster than conventional smoking, resulting in more throughput per unit.

Liquid smoke is commonly prepared by pyrolysis of hardwood sawdust. The smoke is captured in water by drawing it countercurrent to water through an absorption tower. The smoke is recycled until the desired concentration is reached. The solution is then aged to allow time for polymerization and tar precipitation. It is then filtered through a cellulose pulp filter, which removes any dissolved hydrocarbons that are present in the liquid smoke. These liquid smoke solutions may be used without further refinement. The final product is composed primarily of the vapor phase, and contains mainly phenols, organic acids, alcohols, and carbonyl compounds. Analyses of several liquid smoke preparations have shown they do not contain polycylic hydrocarbons, especially benz[*a*]pyrene. Animal toxicity studies have also supported the chemical analyses indicating that all carcinogenic substances in smoke are removed during production of liquid smoke.

Application of Liquid Smoke

There are a number of ways of adding liquid smoke to food products, including (1) adding it directly to the meat emulsion; (2) dipping the product directly into the smoke solution; (3) spraying the smoke solution over the product; (4) atomizing the liquid smoke into a dense fog and injecting it into the smokehouse; and (5) vaporizing the liquid by putting it on a hot surface. The latter three methods are commonly used for smoking meats, with the spray method most frequently being utilized for continuous meat processing.

Liquid smoke preparations are usually diluted before applying to meats. Commercially prepared liquid smoke solutions are diluted with water, or frequently with vinegar or citric acid. A typical liquid smoke solution prepared and used by meat processors consists of 20 to 30 parts liquid smoke, 5 parts citric acid or vinegar, and 65 to 75 parts water. Citric or acetic (vinegar) acids are used to enhance skin formation on skinless frankfurters and other small sausage products. Although skin formation can be achieved by spraying with liquid smoke alone, a higher concentration of smoke is required. Thus, acid added to the smoke solution reduces costs.

Use of liquid smoke makes it much easier to keep equipment clean, since deposition of tar and other residues from natural smoke requires frequent cleaning. Failure to clean regularly can result in spontaneous fires. The atomizing or spraying systems that are used to apply liquid smoke can also be adapted for use in cleaning smokehouses.

Even though liquid smoke does away with the smoking process, cooking is still required for most meat items. Thus, it is necessary to provide cooking facilities even though the smoke generator is eliminated. Cooking after spraying with liquid smoke preparations is essential to give good smoke color formation. This is the reason that such smoke preparations should be added just before cooking.

Several methods for adding liquid smoke other than spraying have been used. These include addition to the formula and dipping, but neither has been as successful as spraying. Figure 4.6 shows a smokehouse with liquid smoke being injected through nozzles.

Present trends suggest that liquid smoke will largely replace natu-

FIG. 4-6. Smokehouse with liquid smoke injection. Courtesy of Red Arrow Corp., Manitowoc, Wisconsin.

ral wood smoke. The speed with which this occurs will no doubt depend on automated procedures and on the relative freedom from carcinogenic substances. Manufactures and jobbers of liquid smoke are presently enjoying an excellent demand for their product and every indication points towards a continuation of this trend.

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5

Meat Cookery and Cooked Meat Products

The origin of meat cookery is older than civilization itself, and, like meat curing, probably first occurred accidentally when fresh meat was exposed to fire and/or heat. This theory has some support in the classic treatise entitled "Dissertation on Roast Pig" by Charles Lamb, the famous English author who lived during the latter part of the eighteenth and the early part of the nineteenth century. According to Lamb's humorous account, the ancient Chinese kept their pigs in the houses as pets, and after the accidental burning of one house along with the pigs, they learned that "roast pig" was indeed a delicacy. In fact, Lamb satirically suggests that it became a custom to purposely set fire to their houses as a means of preparing roast pork.

Regardless of the origin of meat cookery, it not only improved palatability but also reduced the incidence of spoilage by partial destruction of the bacterial flora. Thus, cooking meat improved the keeping qualities and extended its storage life. Cooking not only contributed to the stability of meat products, but also played a most important role in providing a variety of meat products, which can be achieved solely by modifying cooking procedures. Therefore, meat cookery has contributed greatly to advances in civilization and has helped to make it possible for a limited number of people to feed the masses.

ACTION OF COOKING

Although the cooking methods used in preparing processed meat products are generally not the same as those used for fresh meats, they are based on the same principles and utilize the same basic techniques. Therefore, this discussion will consider the action of cooking in general, with special emphasis on any variation from the traditional during processing.

Cooking has the following effects on meat and meat products: (1) it coagulates and denatures the meat proteins, at the same time altering their solubility and effecting changes in color; (2) it improves meat palatability by intensifying the flavor and altering the texture; (3) it destroys considerable numbers of microorganisms and improves the storage life of meat products; (4) it inactivates indigenous proteolytic enzymes and prevents development of off-flavors; (5) it decreases the water content of raw meat, especially on the surface, which in turn lowers the water activity and improves the peelability of frankfurters and extends their shelf life; (6) it stabilizes the red color in cured meats, and (7) it modifies the texture or tenderness of meat and meat products.

Denaturation and Changes in Solubility

Upon cooking meat, the first physical change evident is coagulation on the surface. As this occurs, the color changes from red to gray or grayish brown. Coagulation is also accompanied by denaturation of the proteins, which can be measured quantitatively by determining their decreased solubility in selected solvent systems relative to their solubility prior to cooking. In cured processed meat, the color does not become grayish-brown as cooking proceeds, but the nitrite reacts with the muscle pigments to produce a stable pink color (see Chapter 3). However, denaturation and solubility changes appear to be the same as for fresh meat.

Although the exact nature of denaturation and coagulation is not fully understood, there are distinct and easily recognized physical changes in meat proteins during cooking. Solidification of the muscle juices and color changes are readily observable and are closely associated with the alteration in solubility. The initial changes are confined to the surface, but as time and temperature are increased, the action penetrates further into the interior of the meat. Thus, well-done meat will show the characteristic coagulated gray appearance even in the center of the cut. These changes can be easily observed in canned meat or in precooked frozen meat. In fact, when precooked frozen meat is imported into the United States from countries where hoof-and-mouth disease occurs, lack of the characteristic gray color is a basis for rejection, since the meat must be "thoroughly cooked" to destroy the causative virus. The more complex changes, which are manifested by decreased solubility, are not always readily observable.

Denaturation and coagulation involve changes in the protein molecule. This may be due to unfolding of the protein or the loss of its characteristic conformation, which decrease its solubility. Obviously, there could be changes in the number of lipophilic (fat-loving) and hydrophilic (water-loving) bonds, which will greatly affect the solubility in any solvent system.

Denaturation and the accompanying changes in solubility have a most important function in emulsion-type sausages. During chopping the fat is coated with protein. Myosin in particular plays a very important role in completely covering the fat particles. Once the fat is coated with myosin, it is stable only for a period of hours, or at most about a day. Heating the emulsion, however, coagulates the protein and stabilizes the emulsion, so that the protein holds the fat in suspension for an unlimited period of time. Thus, cooking has an important function in the manufacture of emulsion-type sausages such as frankfurters and bologna.

Improvement in Palatability

Cooking is a most important factor in improving the palatability of meat products. Although some people like raw meat, the majority prefer the flavor and aroma of cooked meat. Cooking intensifies the flavor of meat and changes the "blood-like" or "serumy" taste of fresh meat to the pronounced cooked flavor and aroma.

The aroma or odor predominates after cooking, whereas taste is the major flavor component in raw meat. Although the aroma of cooked meat has a characteristic sulfury note, there appear to be a number of other components that make important contributions to the odor. Taste becomes relatively less important as the aroma develops during cooking, but the taste of cooked meat is still very important.

The sensation of flavor, which is the combined reaction to taste and odor, is variable, and depends on the following factors: (1) species, (2) age of the animal, (3) method of cooking and addition of curing agents and seasoning ingredients, (4) amount and kind of fat in both the raw and cooked product, (5) post-slaughter aging of the meat, and (6) the characteristic flavor imparted by pre-slaughter feeding regimes. All or some of these factors may form different combinations, and thereby produce a variety of flavors.

There are distinctly different flavor characteristics in the meat from different species. Research suggests that the basic meaty flavor is essentially the same in all kinds of meat, and is probably associated with the amount and kind of sulfur compounds. The species-characteristic flavor, on the other hand, appears to be due to the components of the fatty tissues, probably the carbonyl compounds.

Generally speaking, meat from older animals has a more pronounced or stronger flavor than that from young animals. This fact is reinforced by comparing veal with beef, or lamb with mutton. Although some people prefer stronger flavors, others show a distinct preference for the milder flavor of younger animals. There may often be a compromise between flavor and tenderness, since young animals are more tender but have less flavor.

Methods of cooking can profoundly influence the flavor of meat; in fact, it is questionable if any other factor is so important. Browning of meat, various flavor additives used in cooking, and a variety of modifications during cooking markedly affect the flavor of the end product. The contribution of browning to meat flavor was evident in early work on dielectric cooking, where prebrowning was found to be necessary to make meat cooked by this process palatable. Roasting, frying, broiling, braising, stewing, and boiling will all produce characteristically different flavors in meat products. The effects of adding salt, onions, garlic, tomatoes, spices, and other ingredients during the cooking process are well-known, and are especially important in processed meat.

Both the amount and kinds of fat present have an influence on the flavor of meat products. Mutton and lamb are generally used in limited amounts because of the flavor of the fat. Since the fat is believed to impart the characteristic species flavor, not only the kind but the percentage of fat will have a great influence on the characteristic flavor of various meat products. Boar meat, particularly the fatty tissue, should not be used in sausages to be heated before use, since an undesirable odor emanates from the fat on heating. However, boar meat can be used in products to be eaten cold, since the undesirable odor is only evident on heating. Recent studies in Australia using formalin-treated unsaturated fats have suggested that alteration in the proportion of saturated and unsaturated fat can have a profound influence on the flavor of meat, producing products with quite different flavors than those that normally occur.

Post-slaughter aging alters the flavor of meat. Some people prefer the full, rich flavor of aged meat, whereas others object to the stronger flavor and prefer fresh meat flavor. For processing, it is advisable to use meat that has not been aged. Aged meat often tends toward rancidity and creates other problems. Therefore, meat to be processed should be used as soon as possible after slaughtering.

Various feeds influence the flavor of meat. Clover, alfalfa, and rape pastures produce strong and sometimes objectionable flavors in lamb. Similarly, fish meal and certain other feeds impart off-flavors to pork. Wild onions and garlic are also known to impart undesirable flavors and aromas to beef carcasses of animals pasturing these plants during the spring of the year. Thus, off-flavors and odors can sometimes be traced to the pre-slaughter feeding regimes of the animals. These problems can usually be prevented by putting the animals on more conventional feeds for a few days before slaughter.

Tenderness can also be altered by methods of cooking. Moist-heat cookery methods produce more tender meat than dry-heat cookery. The carcass commonly has tender and less tender cuts, so the less tender cuts should be cooked by moist heat. The tender cuts are normally cooked by dry heat, because they remain tender even when cooked by this method. Since sausages are usually chopped or emulsified, they are generally tender, and moist-heat cookery is not required. Live steam is often added to the smokehouse during cooking to accelerate the rate of temperature increase. In modern high-velocity smokehouses, the same effects can be achieved at low relative humidities, so moist-heat cookery may not be encountered.

Destruction of Bacteria and Improving Stability

Cooking performs a most important function by causing destruction of spoilage organisms. The number of organisms destroyed will depend on the time and temperature relationship. In normal roasting, broiling, braising, or frying, the bacterial population is reduced by the influence of temperature and time. However, the meat is not sterilized, and the net effect is merely an extension of storage life. By proper handling to avoid additional contamination of the product, along with refrigeration to slow down multiplication of bacteria, the storage life is extended from a few days to a week or more. The length of storage will depend largely on the care taken to prevent microbial growth by recontamination, or by conditions favoring the growth of the organisms still present on the meat.

Commercial sterilization of meat products can be achieved by subjecting them to high temperatures for a sufficient length of time to destroy most of the microorganisms present. This is a normal procedure in canning meat, which results in not only the destruction of the vegetative cells but also of some bacterial spores to produce a commercially sterile product.

In the manufacture of sausages and smoked meats, cooking is done primarily to produce a table-ready product. However, cooking also plays a major role in extending the shelf-life of such products. Sausages and smoked meats are normally quite stable under refrigeration (32°–38°F), provided they are properly handled and packaged to prevent contamination after cooking. Although the raw ingredients in sausages are subject to spoilage within a few days, finished sausages can normally be stored for several weeks after cooking. This shows the importance of cooking on the stability of processed meat.

The storage life of sausages and cured meat may be limited by the growth of molds. Although vegetative molds are destroyed by cooking, at least some spores remain viable. However, as mold spores are almost universally present in the air, recontamination frequently occurs and constitutes the major problem. Proper cooking lowers the moisture content, particularly on the surface, and thus greatly reduces problems from molds. When proper packaging follows cooking, mold growth can be almost entirely eliminated.

Inactivation of Indigenous Enzymes

Enzymes present in raw meat normally do not cause marked changes in palatability, because enzymatic degradation is relatively slow in producing undesirable organoleptic changes. Under usual storage conditions, microbiological spoilage will occur before the proteolytic changes become objectionable. However, it has been found necessary to inactivate the proteolytic enzymes present in raw irradiated meat in order to prevent deleterious flavor changes due to proteolysis. After prolonged storage of irradiated raw meat at temperatures from 60° to 100°F, the flavor becomes bitter and tyrosine crystals may be isolated, all of which indicate extensive proteolysis. Heating to internal temperatures of 135° to 145°F appears to be adequate to prevent further proteolysis in irradiated meat. This heat treatment is now commonly used for all irradiated meat items.

Surface Drying

Reduction of moisture at the surface of meat and meat products serves several purposes. As already discussed, lowering of surface moisture reduces the water activity (relative vapor pressure) on the surface and thus also reduces microbial growth. The reduced surface moisture content plays a key role in preventing not only the growth of surviving bacteria, but also the growth of any other bacteria that may recontaminate the product.

Surface drying during cooking is also responsible for skin formation in production of skinless frankfurters and similar products. Coagulation of the surface proteins results in the formation of an outer layer that serves as a skin when the cellulosic casings used during sausage manufacture are removed. Thus, the skin formed during cooking is a function of the cooking time–temperature relationship. The nature of the skin is most important for peelability or removal of the casing. Drying of the surface also aids in giving the skin a dense texture and imparts the characteristic appearance of skinless products. Although the ingredients have some influence on peelability, proper cooking without excess shrinkage and wrinkling are important in imparting good peelability. The cooking process not only serves the function of producing a skin but also must be carefully controlled to make the product readily peelable and of good appearance.

Color Development

Cooking has an important function in stabilizing the red pigments formed by the action of nitrite with myoglobin and hemoglobin. The nature of the reactions and the function of heat have been discussed in detail in Chapter 3.

METHODS OF COOKING

Basically, there are three methods of cooking meat: (1) dry heat, (2) moist heat, and (3) microwave cookery. In actual practice, it is difficult to reduce all methods of cookery to such a simple classification system. Often cooking procedures are combinations of the two methods, i.e., part of the process may be dry heat and part moist heat. These same basic cooking methods are used for both fresh meat and processed meat.

Dry-Heat Cookery

During dry-heat cooking, the meat is surrounded by hot air, such as occurs in oven-roasting or broiling. Frying in fat and pan frying are also considered to be dry-heat methods of cookery. Dry-heat cooking is recommended only for relatively tender cuts of meat. Dry heat is the common method in low-humidity cooking in smokehouses. High-velocity air-conditioned smokehouses use this method almost exclusively, since the relative humidity seldom exceeds 70%.

Moist-Heat Cookery

Cooking by moist heat makes use of hot liquid or steam. Most frequently water is added during cooking. The moisture is generally kept in contact with the meat by recirculating it to prevent its loss. In fresh meats, this is usually accomplished by covering the container with a lid, which causes most of the steam to condense and to be available again for generation to steam. Stewing, braising, pot-roasting, simmmering, and swissing are all commonly used moist-heat cooking procedures. The small increase in pressure that results from using a closed system gives slightly higher cooking temperatures, and is quite effective in gelatinizing collagen. If one desires an even higher temperature, this can be achieved by use of a pressure cooker, which is also a moist-heat cooking method.

Live steam is frequently injected into some of the older smokehouses to accelerate the rate of temperature rise during the final phases of processing. This is a moist-heat method, as is the use of a Jourdan cooker, in which the product is removed from the house and finished off with steam. Since the temperature is quite uniform throughout modern high-velocity smokehouses, steam is seldom injected, making it essentially a dry-heat process.

Combination Methods of Cookery

As already mentioned, cooking can be and is often accomplished by methods that combine moist-heat and dry-heat methods. These procedures can utilize the advantages of both methods. During cooking of sausages, it is not unusual to start processing with the damper open, thus using a dry-heat method. After the proper amount of drying has been achieved, the damper may be closed and live steam injected, which raises the humidity and converts the process to moist-heat. As already mentioned, using a Jourdan cooker following traditional smokehouse cookery at low relative humidity is also a combination dry- and moist-heat method.

Another example of the combination procedure is braising, where meat may be browned over high heat before adding water. During the later phases of cooking, the pan is covered. This results in a moist-heat cooking method. The braising procedure has the advantage that the flavor is developed under dry heat while the tenderizing influence of moist heat is retained. Covering a roast without adding water retains the moisture present in the meat; the humidity of the heated air is raised, which helps to hydrolyze the collagen. This is a combination of the dry-heat and moist-heat methods. Injction of live steam into older smokehouses or use of a Jourdan cooker to accelerate temperature increase during the later phases of cooking reverses the order from that applied in braising fresh meat. Thus, dry heat is used first and moist-heat methods later.

Microwave Cookery

Microwave cookery makes use of a portion of the electromagnetic spectrum. Since part of the frequency range of 1 to 100 cm is assigned to radar communications, the Federal Communications Commission has allocated specific frequencies for industrial, scientific, and medical uses. The two commonly used frequencies for microwave heating are 915 and 2450 MHz with wavelengths of 32.8 and 12.25 cm, respectively.

Although most of the currently available microwave ovens operate at 2450 MHz, there is a great deal of interest in the 915 MHz frequency. This frequency produces two peaks, one at the surface and the other at the center, whereas the 2450 MHz frequency produces only the surface peak. Two peaks result in faster and more uniform heating with lower cooking losses and thus are more energy efficient. The higher frequency (915 MHz) also gives slightly greater product penetration in fresh meats, but much greater penetration in frozen meats. Thus, it has distinct advantages in tempering or thawing of frozen meats.

The generator or power tube of conventional microwave ovens is called a magnetron. It is a diode vacuum tube that controls the flow of electrons by an externally applied magnetic field to generate microwave frequencies. The 2450 MHz frequency was preferred in earlier ovens because the higher wavelength tended to burn out the magnetron. However, the magnetron can now be protected to extend its operational life materially so that the 915 MHz frequency has become practical. It seems likely that microwave ovens of the future will largely utilize the 915 MHz frequency. There is also some likelihood that the future for 915 MHz microwave ovens will be in solid state electronic power units.

Microwave heating is accomplished in a microwave oven, which contains eight major components: (1) a power supply, which adapts line power to the generator requirement, and ancillary components; (2) the generator or power tube, which converts the power supplied into microwave energy; (3) the transmission section for propagating the energy to the oven proper; (4) coupling devices, which transfer the energy to the load; (5) distribution devices that deliver the energy in a uniform interaction pattern; (6) the oven itself, which is constructed so as to provide a resonant structure for efficient energy transfer; (7) an energy scaling and trapping structure to prevent the escape of radiation; and (8) operating controls and safety devices for selection of cooking conditions and protection of the operator.

In principle, the microwaves are directed and reflected from the metal walls back and forth through the food (a dielectric substance) so that the food absorbs energy from the electromagnetic field. Upon being absorbed by the food, the energy is converted to heat by intermolecular collisions. Thus, microwave cooking is radically different from conventional cooking methods, since heating is within the food per se and not by transfer of heat from the surrounding environment. The surrounding environment in the microwave oven is commonly cold air, and only the temperature of the food or load is raised during the cooking process.

Microwave cookery has several advantages over conventional methods of heating, including the following: (1) rapid heating, (2) uniform heating, (3) a wide degree of selectivity, (4) ease of control, and (5) lower energy usage. There are also a number of limitations that microwave cookery suffers from: (1) the speed of heating depends on quantity of the load, (2) excessive steaming may produce sogginess in some products, (3) preferential absorption of microwave energy by thawed portions may raise the temperature excessively high while the center may still remain frozen, (4) heating may not be the same in all areas of the oven, (5) foods to be cooked must be in containers other than metal since microwaves do not penetrate metal, and (6) microwave cooking does not develop brownness. There has been great improvement in design to alleviate many of these problems. In order to overcome the lack of browning, which plays an essential role in cooking of meat, many microwave ovens are equipped with a browning unit that makes use of conventional electric heating to sear or brown the product before cooking is begun by microwaves.

The speed makes microwave cooking highly desirable under many conditions. It is widely used for cooking of meat products under commercial conditions, in view of the fact that only about 5% as much time is required as for conventional cooking. Consequently, it is often used for on-line cooking in commercial meat processing operations. Microwaves are also being used with increasing frequency for tempering and thawing of frozen meat. They are, however, probably finding their greatest application in the foodservice industry, where they are being used for quantity cookery and for reheating of previously cooked and frozen entrees.

As has already been mentioned briefly, the most serious problem of microwaves for meat cookery is the fact that the flavor is not fully developed unless the product is prebrowned. The cooking time is also much more critical than that for conventional cookery in view of its much greater speed. Nevertheless, microwave cooking is being widely used in the meat industry, and in view of its advantages, is likely to continue to grow in popularity.

CONSIDERATIONS IN SELECTING COOKING METHODS

The characteristics desired in the final product and the nature of the raw material in a large measure determine selection of the type of cooking method. Although roasting gives a desirable flavor, some products will become too tough if cooked by dry heat. Therefore, it may be more desirable to cook by one of the combination procedures or perhaps by a moist-heat method. If the raw material will be tender enough when roasted or broiled, the processor may choose a dry-heat cooking method.

Types of Meats

Tender Cuts. If the cuts of meat are of sufficiently high quality, they may be cooked by dry-heat methods. Prime rib roasts of beef, steaks or roasts from the loin and sirloin, leg of lamb, and fresh or cured ham roasts are usually quite acceptable when cooked by dry heat. Good quality pork, veal, or lamb chops may also be cooked by dry-heat methods. Whole beef rounds, if from good quality carcasses (equivalent to the top portion of U.S. Good grade or above), may be cooked by roasting—a dry-heat method. Similarly, top-round steaks of U.S. Prime or Choice grade may be cooked by broiling.

Ground or comminuted meats are also sufficiently tender to permit cooking by dry-heat procedures. The amount of shrinkage is relatively low in dry heat, so it is used wherever possible because of greater yields. Combination dry-heat and moist-heat cooking methods are frequently used to reduce shrinkage and still tenderize and give good flavor. Such combination procedures are frequently used in production of precooked frozen meat items for heat-and-serve meals.

Tough Cuts. Shank meat, heel of round, breast of lamb, and chuck roasts of beef are usually classified as less-tender cuts. They generally give best results if cooked by moist-heat or combination methods. Thus, they are commonly cooked by braising, stewing, swissing, simmering or pressure-cooking. In order to reduce shrinkage losses, these cuts are often cooked in casings or packaging materials that prevent evaporation and hold the juices lost during cooking. Phosphates may be added to some of these products to help retain the juices, thereby increasing yields.

Processed Products. Sausages, hams, and roasts for precooked frozen meals are often cooked by combination methods to reduce shrinkage and improve flavor. Obviously, these procedures also will give tender products. Some loaves are browned in hot fat to improve appearance, flavor, and aroma. Comminuted meats are tender and do not normally require moist heat to improve tenderness, but combination dry- and moist-heat procedures are often used to speed up processing and give more throughput.

Specific Cooking Methods

A number of methods will be considered with more specific recommendations for their use. It should be borne in mind that the recommendations apply only to products and cuts and not to specific temperatures and procedures. Specific methods for making processed meat items will be given in more detail later in this chapter.

Broiling. This is a dry-heat procedure that is used for more tender steaks from beef, chops of lamb, and cured ham steaks. The meat is usually supported by a wire grill and the heat may come from above as in an electric or gas oven, usually at full heat, or from below as with a charcoal broiler. After the side exposed to the heat is sufficiently done, the meat is turned over and finished on the other side. About two-thirds of the total time is required for the side cooked first and one-third on the last side. However, the degree of rareness or doneness desired will determine the timing.

Some broilers have reflectors on the side opposite from the heat that permit simultaneous cooking on both sides. One merely cooks the meat until the desired degree of doneness is reached in the center. However, most professional cooks prefer to turn the meat, feeling that this gives better control.

Broiling is not normally used in processing of meats. It may, however, be used as the heating method just prior to eating processed products, such as cured ham slices, precooked frozen meat in the form of steaks or roasted slices, or for heating various types of sausages. Frozen meat patties or hamburgers are also frequently cooked by this procedure before eating.

Roasting. This is another dry-heat method of cookery that is suitable to more tender cuts of meat. Prime rib roasts of beef, beef sirloin, top round, sirloin tip, veal leg, veal rump, veal shoulder, pork loin, pork shoulder, leg of lamb, shoulder of lamb (whole or rolled), lamb loins and racks, and cured hams are commonly cooked by roasting. Entire beef rounds can also be cooked in this manner if of high enough quality.

The roast should be at least 2½ in. thick. It is placed in an open roasting pan with fat side up, so that it will be self-basting. The roast should be left uncovered and liquid should not be added. The roast is placed in a hot-air oven at a temperature of 250°–350°F. Lower oven temperatures require longer cooking times but materially reduce shrinkage. High temperatures (400°F) may be used for a short time to brown the roast and improve the flavor during the last 15 to 20 min of cooking.

Roasting may be used in preparing precooked frozen beef. However, these products are more commonly cooked in water, usually in plastic bags, to retain the juices and reduce shrinkage. Roasting as the final step in preparing various precooked frozen meat items for eating is common.

Frying. Frying is classified as a dry-heat method. It may be accomplished in a small amount of fat in a frying pan or in a large amount of fat in a deep-fat fryer. It is suitable for relatively small cuts of meat, such as thinly sliced steaks, chops, bacon, veal chops, or lamb chops. It may also be used for chicken parts cut into relatively small pieces. Batter or bread crumb coverings may be used to impart a desirable flavor. This method of cookery is not used for production of processed loaf items, bacon, or ham slices.

Pan frying of bacon has been implicated in the formation of *N*-nitrosopyrrolidine (a carcinogen). The high temperature achieved during the frying operation apparently catalyzes nitrosation of proline to *N*-nitrosoproline, which then is decarboxylated to form *N*-nitrosopyrrolidine. This series of reactions does not seem to occur at the lower cooking temperatures achieved by other cooking methods. As indicated in Chapter 3, formation of *N*-nitrosopyrrolidine is largely blocked by using α-tocopherol-coated salt in the cure.

Braising. This procedure is a combination of dry-heat and moist-heat cooking. It is commonly used for less-tender cuts, such as the rump of beef, chuck roasts of beef, heel of round, breast of lamb, and lamb shanks. It may also be used for pork spareribs, veal chops and steaks, and pork chops and steaks. The meat is usually braised by browning in hot fat in a pan, which constitutes dry-heat cookery. Moisture such as water, vegetable stock, milk, or gravy is then added, together with seasoning. The pan is tightly covered and the meat is simmered by adjusting the heat to just below boiling, which is the moist-heat phase. Vegetables may be added at a time just sufficient to cook them.

Braising is not normally used for processed meat products, although they may be prepared for the table by this method. However, consumers generally prefer faster methods.

Pot Roasting. This method is essentially the same as braising. It is commonly used in preparation of the same cuts as discussed under braising. Pot roasting nearly always makes use of vegetables, which are added at the proper time to be ready to eat with the meat. Otherwise, the procedure is similar to braising.

Stewing. This is a moist-heat procedure. The cuts of meat used are the less-tender ones and are almost always boneless. The meat is cut into small pieces and is usually browned in a small amount of fat, as in braising; however, stews may not always be browned. The meat is then covered with water or tomato juice. The container is covered and the meat is allowed to cook at a simmering temperature. The vegetables are added just long enough before the meat is done so they will be tender but not overdone. The liquid is reduced during cooking to give the stew a slightly thickened consistency.

Stew is a popular canned-meat item. The procedures used in its production are given in complete detail under canned meat items, chapter 12.

Pressure Cooking. One of the most successful methods of tenderizing tough cuts of meat is by pressure-cooking. The use of pressure results in higher cooking temperatures; it minimizes the time required to gelatinize the collagen, and produces tender meat in a relatively short time. Meat cooked under pressure does not usually appear to be dry, but seems relatively moist. It is quite different from meat cooked to high internal temperatures in air, which is generally very dry in appearance and mouth-feel.

Cooking losses are usually higher than those for dry-heat cookery. Another serious problem in pressure cooking is the fact that the meat may lose its normal texture and disintegrate into a rather homogeneous mass of disconnected fibers. To prevent the loss of texture, pressure cooking must be carefully controlled to the correct end-point.

Simmering. Certain cuts of beef and some sausages, such as braunschweiger, may be cooked in water. Generally, these items are heated to temperatures considerably below boiling (160° to 170°F). The hot water provides for relatively fast heat penetration. Most often these products will be heated in casings or plastic bags to avoid excess shrinkage losses. If cook-out accumulates in the bags or casings, it may be saved and utilized.

COOKED MEAT PRODUCT RECIPES

A number of methods of producing some cooked or frozen meat items are given. The list of products is by no means complete. The recipes are given only as guides, and modifications may be developed to suit individual processors.

Roast Beef

Raw Materials. Well-trimmed cow rounds (insides, outsides, or knuckles), shoulder clods, or sirloin butts are used.

Seasoning. The exposed surfaces may be rubbed with salt and other seasoning as desired, or a seasoned pumping solution may be used instead.

Stuffing. Use No. 8 × 30 fibrous casings. Stuff with a press through a 3¾ in. o.d. (outside diameter) stuffing horn.

Cooking. Transfer the rolls into an oven preheated to 300°F and roast until the internal temperature reaches 140°–165°F. The choice of final temperature depends on the degree of doneness desired. Approximately 4½ hr are required to reach an internal temperature of 155°F.

Chilling. The rolls should be chilled in running tap water until the internal temperature reaches 100°–120°F. The excess liquid in the rolls may be removed and the rolls repacked under pressure.

Yield. The final yield depends on the cooking temperature, final internal temperature, and casing size.

Frozen Boneless Pork Loin Roasts and Chops

Raw Materials. Use boneless pork loins weighing 5½ to 10½ lb. Bone-in loins weighing 12–18 lb will give boneless loins of the weights desired and will meet military specifications for these products. In addition, powdered egg white (low whip-*Salmonella* free) is needed for binding.

Preparation and Stuffing. The loins are boned and trimmed. Each loin is cut in half, dipped in egg white, and opposite ends are placed together, i.e., blade end to ham end. Stuff the loin into No. 7 casings, using 401 can lids if the loins are going to be cut into chops. After the loin is stuffed, it should be pressure-packed until it is approximately ½ in. less than the recommended stuffed casing circumference. This allows for expansion due to freezing. To minimize casing breakage during freezing, the loins should be individually wrapped in thin polyethylene sheets.

Cutting Loin into Chops. If the loin is to be cut into chops, it can be sliced with a frozen meat slicer as soon as it reaches 26°–28°F. This firms the meat up sufficiently for slicing, but minimizes the problems encountered on slicing at low temperatures.

Government Specifications. Military procurement specifications for frozen chops call for each chop to weigh 5 oz plus or minus ½ oz. Individual chops must not exceed ⅞ in. or be less than ½ in. thick.

Storage. Frozen loins should be stored at temperatures no higher than 0°F, −25°F or lower being preferable. Loins should be moved into commercial outlets or military procurement routes as soon as possible after freezing. They should never be stored longer than 6 months, and preferably no longer than 3 months. The loins are subject to development of rancidity, and storage at lower temperatures and shorter times tends to prevent this.

Cooking. The loins are cooked by roasting; the sliced chops are generally broiled, pan-fried, or grilled.

Frozen Boneless Pork Shoulder and Ham Rolls for Roast or Chops

The product described is largely intended for large-volume institutional kitchens. Boneless rolls are versatile, excellent for portion control, and have a uniform composition.

Raw Materials. This product can be prepared from pork picnics, skinned shoulders, Boston butts, and skinned hams. According to USDA Institutional Meat Purchase Specifications, the weight limits are no larger than 8 lb for picnics, 14 lb for skinned shoulders, 6 lb for Boston butts, and 16 lb for skinned hams. The bones and skin are removed, leaving all fat on the boneless cut. The shank meat and heavy fat deposits should be removed.

Preparation. The shank meat and excess fat trimmings should be ground through a ⅛ in. plate and the lean cuts through a 1–2 in. plate. The lean cuts should make up at least 70% of the meat block, while the ground shank and fat trimmings should never exceed 30% of the total.

Mixing. Place all the ground meat, both finely and coarsely ground, in a mixer. Add 1 to 1.5% salt. Mix for 4 min. Although vacuum mixing gives the most uniform product and best portion control, it is not an absolute requirement.

Stuffing. The product is stuffed into moistureproof fibrous casings using a piston-type or else a continuous-type stuffer. U.S.D.A. Institutional Meat Purchase Specifications call for 7 lb rolls packaged eight to a box to give a total of 56 lb. To meet these requirements, the casing used is usually a No. 5N × 28 in. The rolls should be pressure-packed to approximately ¼ in. less than is recommended by the casing manufacturer, which allows for expansion during freezing.

Freezing and Storage. Rolls should be frozen as soon as possible after stuffing. Rapid freezing and low-temperature storage provides better stability. The rolls should be handled the same as the frozen pork loins and chops.

Cooking. The frozen chops may be fried, grilled, or broiled. They are also sometimes braised, but generally dry-heat methods are employed. If roasts are preferred, the roll should be placed in an oven at 250°–300°F and cooked to an internal temperature of 170°F. If diced meat is preferred, the rolls should be tempered at 25°–29°F and the casing removed. The roll should be cut into 1-in. thick slices and then cut into small pieces with a knife. The cubed meat can be used for chop suey and stews or ground and used in ground-pork recipes.

Frozen Boneless Beef Rolls for Grilling or Broiling

The product described is a comminuted fresh beef product having the taste and textural properties of beef steak. It eliminates trimming waste, gives careful portion control, and is uniform in composition.

Raw Materials. Boneless beef rounds are used from USDA Prime, Choice, Good, or Standard carcasses. The top, bottom, or knuckle sections of the round may be used.

Preparation. Heavy fat deposits and connective tissue are removed. The poorer parts should be discarded, while the sound material is ground through a ⅛-in. plate. The trimmed lean muscle should be ground through a large plate (either a 1- or 2-in. hole plate or a 1- to 1.5-in. kidney shaped hole plate). The amount of trimmings should not exceed 15% of the total weight, while the large lean muscle portion should comprise at least 85%.

The entire meat block should be placed in a mixer and 1–1.5% salt added. It should be mixed for 4 min. Vacuum mixing is desirable from the standpoint of uniformity and portion control, but is not absolutely necessary.

Stuffing and Pressure Packing. Stuff the product into moisture-proof fibrous casings (using No. 6 to 9) with a piston or continuous stuffer. The rolls should be pressure-packed to a circumference approximately ¼ in. smaller than that recommended for the casing to allow for expansion during freezing. A precision sizer can be used to eliminate the pressure-packing step and improve efficiency and portion control.

Table 5.1 gives the weight that can be expected per linear inch for different moisture-proof fibrous casing sizes. This information is useful in selecting the desired size casing.

TABLE 5.1. Product Weight per Linear Inch for Fibrous Casings of Different Sizes

Casing size No.	Weight per inch (oz)
6	8
7	9
8	11
9	12

Freezing. Rolls should be frozen as quickly as possible after stuffing. Low-temperature freezing and storage improve stability. Storage should be limited to a maximum of 5 to 6 months.

Slicing Instructions. Rolls may be sliced into portion-controlled pieces of the desired thickness. In the frozen state, a power meat saw can be used, or if tempered to 25°–29°F, an electric slicer will be effective. Thawing for 20 min prior to cutting will make it possible to remove the casing before slicing. If the casing is not removed before slicing, it should be removed before cooking.

Cooking. Slices may be grilled or broiled from the frozen or tempered state. The frozen meat will require slightly longer cooking times.

Boneless Turkey Roasts

Raw Materials. Although tom turkeys in the weight range of 20 to 24 lb are preferred, one may also use heavy (16–18 lb) breeding turkey hens.

Preparation of Meat. The necks and giblets are first removed from the body cavity. The tail is cut off and the excess tail fat remaining on the carcass is removed. The wings are removed next to the body, and the drumsticks at thigh joints. The neck flap is cut in half to expose the keel bone. Beginning at the keel bone, one-half of the breast with the thigh attached is removed while leaving the skin in one piece. The entire procedure is repeated on the other side. The thigh is then removed from the breast, leaving as much skin as possible attached to the breast. This gives the greatest amount of skin for covering the roast. All the bone from the thigh is removed and the tendons on the breast are exposed.

Tying the Roast. The roast may be hand-tied by using a metal pan (similar to a bread pan) 5 × 3 × 10 in. One string (about 36 in. long) is placed at the bottom of and parallel to the long axis of the mold. Four strings (about 24 in. long) are positioned about 2 in. apart and at right angles to the long axis of the mold. One half breast should be placed skin down in the mold, and the thigh meat should be positioned skin up on top of the breast meat. All meat masses are then covered with the skin. All strings should then be tied.

A tying machine or a shaping-tying machine can be used to form and tie the roasts. The roast may be seasoned, if desired, by distributing suitable spice ingredients over the meat surfaces.

Processing. The raw roast can be frozen and sold in that form, or it can be cured and/or smoked.

Cooking. The roasts are not normally cooked by the processor. However, they may be roasted by the purchaser to an internal temperature of 160°F in an oven at 250° to 300°F.

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6

Raw Materials

Of basic importance to the manufacture of all processed meats is selection of proper raw-meat materials. Quality of these meats as determined by their chemical and microbiological age should be high, for it is certainly a truism that a finished product can be of no higher quality than the ingredients it contains. When producing smoked meats, the concern is only with primal and subprimal cuts. However, when manufacturing sausage and canned meats, trimmings resulting from fabrication of primal cuts, as well as boneless whole carcass meat from carcasses which do not find a ready market as block meat, are utilized.

SAUSAGE AND CANNED MEATS

For the manufacture of sausage and canned meats, lean skeletal beef and pork are the most desirable raw-meat materials. Veal and mutton are also used, but in much smaller quantities. If used in excessive quantities mutton imparts an undesirable flavor to the finished products. Comminuted processed meat products tend to be quite dry and tough unless sufficient fat is present. Generally, pork and, to a lesser extent, beef trimmings provide most of the fat in sausage and canned-meat formulations.

Federal meat inspection regulations classify animal tissues used for preparation of comminuted meat products as either meat or meat by-products. To classify as meat, tissues must be of skeletal origin and for purposes of labeling need only be referred to as beef, pork, veal, or mutton. Nonskeletal or smooth muscle tissues, such as lips, tripe, pork stomachs, and cardiac muscle are referred to as meat by-products and must be listed separately in the ingredient statement printed on packages.

Tissues vary in moisture–protein ratio, fat–lean ratio, and amount of pigment, as well as in their ability to bind moisture and emulsify fat. These two properties are collectively referred to as the binding ability of a meat. In the trade, sausage ingredients are classified as either binder or filler meats. Binder meats are further subdivided into high, medium, and low categories depending on their ability to bind water and emulsify fat. Meats with high binding properties are lean skeletal tissues, such as whole-carcass bull and cow meat, lean pork trim, and whole-carcass mutton. Beef and pork cheek meat, beef shanks, and veal are of medium value as binders. Low-binding meats contain a large proportion of fat, smooth muscle, or cardiac muscle tissue. These meats include regular pork trimmings, jowls, tongues, and hearts. Another category, meats with very poor binding properties, is referred to as filler meat. While these materials, such as tripe, snouts, lips, skin, and partially defatted tissues, are nutritionally acceptable, their use in comminuted meat products should be limited if overall quality of sausage or canned meat products is to be maintained.

The moisture–protein ratios of various tissues are important in preparing sausage formulas because they provide guidelines in predicting composition of finished products. Approximate moisture–protein ratios of some common sausage ingredients are presented in Table 6.1.

Fat content of meat used for comminuted meat products is influenced primarily by carcass grade and particular cut or type of trimming from the carcass. Variations in fat content greatly exceed those of moisture and protein. If moisture and protein are known, fat content may be approximated by difference, allowing about 0.8% for ash. When selecting meats for comminuted meat products, consideration should also be given to the percentage of myoglobin present in the raw material, principally because of the effect this pigment has on the color of the finished product. Heart and cheek meats are good sources of myoglobin and may be used to advantage in products that tend to be pale in color. A detailed list of raw materials most commonly used in making comminuted meat products is shown in Table 6.2.

There are no generally observed standards for boneless processing meat. However, on occasion, meat graded as No. 1 or No. 2 by the seller is available for purchase. Meat graded No. 1 is of higher quality and usually provides more lean tissue.

TABLE 6.1. Moisture–Protein Ratios

Meat Type	Moisture (%)	Protein (%)	Moisture–protein ratio
Beef hearts	77	16	5
Bull meat	74	21	4
Beef tripe	73	15	5
Beef chucks	72	20	4
Pork cheek meat	72	20	4
Pork head meat	63	16	4
Beef flanks	59	15	4
Pork belly trimmings	54	14	4
Regular pork trimmings	38	9	4
Pork fat	6	1	6

TABLE 6.2. Raw Meat Materials Used for Preparation of Comminuted Processed Meats

Cattle	Hogs	Veal	Sheep
Boneless primal cuts (chucks, plates, flanks, and navels) Trimmings from primal cuts Cheeks Head meat Hearts Tripe Livers Tongues Lips Giblet meat Weasand meat	Boneless primal cuts (hams, loins, shoulders, and bellies) Trimmings from primal cuts Cheeks Head meat Hearts Stomachs Livers Tongues Skins Snouts Giblet meat Weasand meat	Boneless primal cuts Hearts Cheeks Tongues	Boneless primal cuts Hearts Cheeks Tongues

Beef

The following cuts of boneless processing beef are usually quoted in market price sheets which serve the meat industry: whole-carcass bull meat, whole-carcass cow meat, boneless beef (90% lean), boneless chucks, trimmings (85 to 90%), trimmings (75 to 85%), insides, outsides, and knuckles. In addition, the following meat byproducts are sometimes used for the manufacture of comminuted meat products: head meat, hearts, lips, weasand, and giblet meat. When cheeks are trimmed of overlying glandular and connective tissue, the resultant product is called cheek meat, to differentiate it from the untrimmed product referred to only as cheeks. When cheek meat is used in a comminuted-meat formulation, Federal inspection regulations require it to be labeled as either beef or pork, but it need not be referred to as beef or pork cheeks. If, however, the cheeks are not trimmed, they must be listed separately as beef cheeks or pork cheeks. Beef-head meat is removed from the poll of the head. Weasand and giblet meats are used for the cheapest grades of processed meat products. Weasand meat is the muscular tissue surrounding the esophagus. Giblet meat refers primarily to the diaphragm muscle.

Pork

Pork used in comminuted processed products comes from two sources: (1) boned primal cuts, usually from heavy hogs, and (2) trimmings obtained during preparation of primal cuts for curing or merchandising as fresh pork.

Pork trimmings may be either fresh or cured. When primal pork cuts that have already been injected with curing pickle are trimmed, the resultant meat is referred to as sweet pickled trim. Fresh pork trimmings are divided into lean and fat trim. Lean pork trimmings consist of special lean (80%) and extra lean (90%). Fat trim consists of regular and 50% trimmings. Regular pork trim contains 55–60% fat, whereas 50% pork trim contains 45–55% fat.

Veal and Mutton

Veal used in comminuted processed meats is either whole-carcass or veal trimmings. Because veal comes from young animals, there is little fat on the carcass, making both whole-carcass veal and veal trimmings quite lean. On occasion, mutton, usually in the form of whole-carcass meat, is used in processed meat products. Mutton is usually quite dark in color and contributes desirable pigment to comminuted sausage or canned meat formulations. Mutton has good binding properties, but because of pronounced flavor, its usage is usually restricted to 20% or less of the total meat block.

Variety Meats

Variety meats are used in many comminuted processed meat products. Government regulations specify that variety meats must be labeled specifically as to origin. Those finding greatest use in processed meat products are tongues, livers, hearts, tripe, and pork stomachs. Three types of tongues or tongue trimmings are available: (1) tongues, (2) tongue trimmings, and (3) tongue meat. Federal inspection regulations require that all glandular and connective tissue obtained when long-cut tongues are converted to short-cut tongues be identified as tongue trimmings and further identified according to species. Trimmings from the tongue itself must be referred to as tongue meat and identified according to species. Tongue meat, however, may not include tongue trimmings. Tongues are scalded to remove the mucous membrane.

Most beef, calf, and lamb livers are sold fresh; hog livers are used primarily for the manufacture of liver sausage and braunschweiger. Regardless of ultimate use, the gallbladder is always removed from the liver immediately after the liver is cut from the carcass. Livers are not generally scalded, except in processing some types of braunschweigers.

When heart or heart meat is used for the manufacture of processed meats, the label must indicate species. Hearts are classified as either heart or heart meat. Heart meat refers to the trimmed heart with the cap removed.

Beef tripe is obtained from the paunch. The paunch is trimmed free of adhering fat, opened, and the contents removed. It is then washed and scrubbed. The mucous membrane covering the inner surface of the tripe is removed during the scrubbing operation. For use in processed meats, tripe is frequently scalded and cooked.

Pork stomachs are prepared similar to beef tripe. The stomachs are opened and washed and the mucous membrane removed during the washing operation. They also may be scalded before being used.

Mechanically Deboned Meat

With the increasing availability and relatively favorable price, mechanically deboned meat is frequently being utilized in processed meats. In fact, this is probably the best use of this relatively new raw material. It is most commonly utilized in sausages, but shows promise in restructured meats and hamburger. The levels used should be carefully controlled, however, as too much can cause structural and flavor problems. In sausages, the best levels appear to be from 5 to 10%, with amounts above 20% having adverse effects. In all cases, only fresh high quality mechanically deboned meat should be used or quality problems will ensue.

Mechanically deboned meat can originate from any of the species, including beef, pork, lamb and poultry. Although current Meat Inspection Regulations require labeling to indicate that the products contain mechanically deboned meat, this does not apply to mechanically deboned poultry meat, which can be labeled simply chicken or turkey meat, probably because deboned chicken and turkey meat have been available and utilized by the meat industry for a longer period of time. Mechanically deboned poultry meat can be obtained with and without the skin, with the skinless product being more valuable since it is lower in fat. Deboned poultry meat also tends to have a higher initial bacterial content than the red meats due to the fact that the long bones are open to the air sacs. Furthermore, the fats are more unsaturated resulting in a greater susceptibility to oxidation. However, careful handling, low temperature control, and rapid processing avoids these problems and results in high quality products containing deboned meats from both poultry and the red meats.

Poultry Meat

The use of poultry meat for producing processed meats has become increasingly important in recent years, with both chicken and turkey meat being widely used. Some meat processors purchase either bone-in or boneless chicken and turkey breasts and thighs and use them in producing chicken and turkey rolls or turkey ham. These products are also being produced by poultry processors. Since the principles involved in production are similar for processing both red meats and poultry, there is a trend toward integration.

Poultry meat can be purchased either as whole birds or as specific cut-up poultry parts, which include breasts, thighs, wigs, backs and necks. They may be obtained either with or without the skin. In the case of necks, wings and backs, the skin-on product is considerably less valuable because the skin comprises a considerable proportion of the total and is high in fat and connectives tissues. These three cuts are generally used for producing deboned meat, which has already been discussed in this chapter.

There are no standard specifications or price quotations on poultry carcasses and their parts. Thus, processors purchasing poultry carcasses or parts should develop their own specifications, based on composition or the proportion of lean to fat, the amount of kidneys (in the case of backs), the skin content, and the maximum allowable total microbial count. Some processors also include specifications for maximum allowable 2-thiobarbituric acid (TBA) numbers as a measure of allowable levels for rancidity, whereas, others have doubts as to its usefulness.

In common with the red meats, only high quality fresh raw poultry carcasses and parts should be used for processing. Careful temperature control is essential both before and after purchasing to maintain the quality of the raw poultry meat.

Thawing of frozen meat can be done in a cooler operating at 50°F or in cold running water. Microwave heating is rapidly replacing air or water as a means of thawing and tempering of frozen meat. Since microwaves penetrate further, the speed of thawing or tempering is greatly accelerated. This permits tempering or thawing of entire cases or boxes of frozen meat. Trimmings used for making comminuted meats need not be thawed, but can be sliced or cut into small enough pieces to be fed into a meat grinder or sausage chopper. Using the meat while still frozen will help in controlling the temperature during chopping, although chopping times will be increased.

Partially Defatted Tissue

Partially defatted beef and pork tissues are subjected to low-temperature rendering to remove fat without denaturing the protein. Two types of partially defatted tissues are available, chopped and fatty. Chopped tissues can be used in meat sausages in unrestricted amounts, but fatty tissues cannot be used without restriction in meat products and are limited to a level of 15% by Federal inspection regulations.

SMOKED MEATS

Hams

Fresh or green hams, as they are often called in the packing industry, are not sold according to quality grades but rather according to weight grades. Market prices are generally quoted on the basis of the following weight grade classifications: below 14, 14–17, 17–20, 20–25, 25–30, and over 30 lb. Lighter weight hams, those below 20 lb, are generally of higher quality than heavier hams. Hams weighing in excess of 20 lb come from more mature hogs, frequently sows. Heavy hams usually are darker in color, coarser in texture, and less tender than lighter hams. If they are not used in comminuted meat products, heavy hams are frequently boned and sectioned. Individual sections are canned or processed in stockinettes, casings, or metal molds for sale as individual ham units. Heavy hams are often made into cooked or boiled hams. Since these hams are sliced thin and eaten cold, problems of coarse texture, toughness, and sex odor are minimal.

Since very little ham is consumed fresh, most hams are traded within the packing industry between slaughterer and processor. In addition to weight grade, the value of green hams is affected by (1) trim style, (2) length of shank, and (3) length of butt.

Hams are classified according to trim style as (1) rough, (2) regular, (3) skinned, and (4) skinless. Market prices are quoted for skinned hams unless otherwise specified. Rough hams are untrimmed hams with only the foot removed. No additional trimming is done. Regular hams are produced by removing the tail bone and flank in addition to the foot. Skinned hams have the foot, tail bone, flank, and half of the skin removed. Skinless hams are trimmed like skinned hams, except that all skin is removed. Both skinless and skinned hams have excess surface fat removed and are beveled toward the butt end. Hams represent from 22 to 28% of a carcass, or about 17 to 19% when prepared as skinned hams.

Green hams are sold with the foot removed at the hock. However, they can be purchased as short-shanked hams with the foot cut off close to the body. In another case, the foot is removed below the hock. Such hams are referred to as long-shanked hams and are used primarily for preparation of Country hams.

Hams are usually separated from the loin by cutting between the second and third sacral vertebrae parallel to the angle of the hock joint. Depending on the market for pork loins, hams can be separated from the loin closer to or farther from the aitch bone. The closer a ham is cut to the aitch bone, the smaller the ham butt.

The anatomical structure of a ham lends itself to division into either two or three primary sections. Bones in a ham are shown in Fig. 6.1. It is necessary to understand the position of these bones before a ham can be sectioned properly.

One method of division separates a boneless ham into two sections, (1) cushion and (2) knuckle. Most of the butt and shank meat remain with the cushion. The cushion section comprises 75–80% of the total boneless ham weight, the knuckle—called cap in certain areas of the country—accounting for the remainder. Prior to sectioning, all bones are removed in the conventional manner. Figure 6.2 shows a ham with

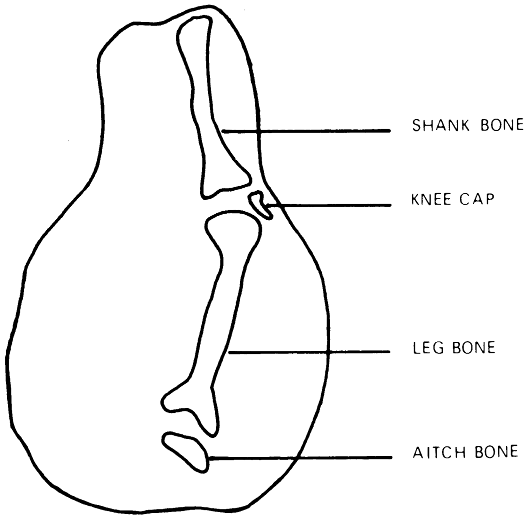

FIG. 6-1. Position of bones in ham.

all bones positioned and an approximate point of division used to section a boneless ham.

Another method of sectioning a boneless ham is to subdivide the cushion into top and bottom sections corresponding to (1) top or inside and (2) bottom or outside rounds of a beef carcass. Together with the knuckle, inside and outside sections constitute the major natural mus-

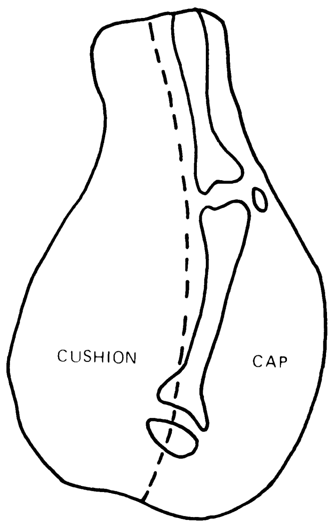

FIG. 6-2. Boneless ham sectioning.

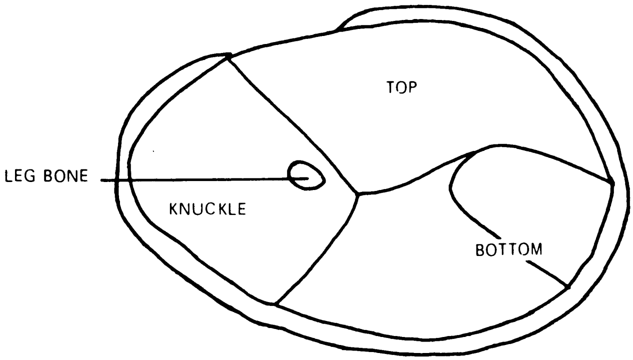

FIG. 6-3. Muscle groupings of center cut ham slice.

cle groupings of a ham. When reviewed as component pieces of a centercut ham slice, the muscle groupings appear as shown in Fig. 6.3.

Because of widespread reluctance on the part of consumers to purchase pork products with even moderate amounts of fat and connective tissue, sectioned hams are usually well trimmed. A well-trimmed boneless ham has a boning yield of approximately 60% based on pumped weight. When a boneless ham is sectioned, approximately 25% is top, 27% is knuckle, 30% is bottom, and 18% is shank and butt meat.

Bellies

Rough bellies refer to untrimmed bellies with the spareribs in place. Trimmed bellies with the spareribs removed and the ends and sides trimmed constitute about 14% of carcass weight. Trimmed bellies can be purchased with the skin or rind either on or removed. Processors using bellies from their own slaughter operations to produce bacon for slicing derind them prior to processing. Fresh belly skins have more market value than processed skins. In either case, bellies are sold according to weight grade. Prices for the following weight grades of skin-on bellies are quoted on most markets: 10–12, 12–14, 14–16, 16–18, 18–20, and 20–25 lb. The grades for derind bellies are 9–11, 11–13, 13–15, 15–17, and 17–19 lb. Approximately 9–11% of the belly weight is in the skin. As is true with all lean primal cuts of pork, heavier bellies have less quality and more fat than do lighter bellies. Highest-quality bacon is made from skin-on bellies weighing 10–16 lb. Bellies used for dry salting usually weigh at least 20 lb and generally in excess of 25 lb.

Bellies that are excessively thick contain larger amounts of fat in relation to lean. However, some bellies are too thin to produce quality bacon. Excessively thin bellies are referred to as skippy bellies. Skippy bellies come from either very young hogs or poorly developed hogs of any age. They lack firmness and produce very narrow bacon slices. Skippy bellies are usually used for sausage or number two bacon.

Teats do not accompany quality bellies but are removed in the trimming operation. Likewise, care is taken to remove small pieces of cartilage which may remain when the spareribs are removed. Bacon prepared from bellies with teats left in place is referred to as seedy bacon, while that prepared from bellies with pieces of cartilage remaining is known as bony bacon.

Pork Shoulders

Pork shoulders can be processed as complete shoulders, but, in most cases, they are divided into two primal cuts: (1) Boston butts and (2) picnics. Both Boston butts and picnics are sold according to weight grade, as are other primal pork cuts. Pork shoulders represent about 23% of the hog carcass, or about 14–16% when trimmed. The trimmed shoulder refers to the shoulder with neck bones, ribs, breast flap, and foot removed and one-third collar of skin left on the picnic.

Boston butts are the upper halves of pork shoulders. The usual market weight grades are 4–8 lb and 8 lb and over. Boston butts that have been boned and trimmed are called boneless butts. They are commonly referred to as CT or cellar-trimmed butts, and are sold according to 3 weight grades: 1½–3, 3–4½, and 4½–6 lb.

The term picnic or less frequently, cala, is commonly applied to the lower half of pork shoulders. Picnics are cut from skinned shoulders which have had the rib, neck bone, and breast flap removed and foot cut off at the knee or 1 in. above. Picnics have all skin removed to within 4 in. of the base of the shank, and the fat is beveled to approximately ½ in. thickness. Green picnics are traded on the market graded according to the following weights: 4–6, 6–8, and 8 lb and over.

As with hams, heavier butts and picnics generally come from larger, more mature hogs. These heavier cuts tend to be somewhat darker in color, coarser in texture, and less tender than similar cuts from younger hogs.

Pork Loins

Pork loins are used to produce two smoked-meat products: (1) smoked pork loins, which are merchandised in the form of either chops or roasts, and (2) Canadian bacon. Approximately 20% of a hog carcass is in the untrimmed loins, while trimmed loins represent 14–17% of the carcass. Bone-in pork loins are sold on the market graded according to the following weight classes: 14 and below, 14 to 17, 17 to 20, and 20 lb. and over. They are classified as regular loins. Regular loins have excess fat removed from the tenderloin and not more than ½ in. of fat left covering the outside of the loins. Both blade and ham ends remain on the loin.

Canadian bacon is manufactured from boneless pork loins. The largest muscle in the pork loin, commonly referred to as the strip or sirloin muscle, is removed from heavy loins and sold as a Canadian back, generally weighing 5–9 lb.

Processed Beef Cuts

Beef plates comprised of a brisket and short plate are used to prepare beef bacon and most corned beef. Lean corned beef is also produced from muscles of the round and the shoulder clod. Primal cuts from low-grade carcasses can be used, but the finished products reflect the original raw materials utilized.

Dried beef is generally processed from muscles of the round of lean cattle. On occasion, shoulder clods are also used. The sub-primal cuts utilized are usually removed from carcasses that would find little acceptance for block beef cuts.

STORAGE OF RAW MATERIALS

The life of any raw meat material is related to (1) sanitation and (2) refrigeration. All raw materials should be handled under the most sanitary conditions possible. Unless they are to be used warm directly from the kill floor, meats should be chilled as rapidly as possible to approximately 30°F and maintained at this temperature until used. If trimmings are not to be used within 5 days, they should be frozen immediately and held at 0°F or below. Primal cuts, such as hams and bellies, can be held for longer periods of time before they need to be frozen. Frozen primal cuts such as loins, bellies, and hams must be thawed before being cured.

CERTIFIED PORK

To ensure that processed meat products that are usually eaten without being cooked by the consumer and that have not been cooked by the processor to at least 137°F are free of trichina, pork certified by Federal inspection authorities to be free of trichina should be used. To be certified, pork must be subjected continuously to a temperature not higher than that specified in Table 6.3. The duration of refrigeration at the specified temperature depends on the thickness of the meat or the inside dimensions of the container.

Federal inspection regulations relating to freezing meat to kill trichina, as specified in Table 6.3, read as follows:

Group 1 comprises product in separate pieces not exceeding six inches in thickness, or arranged on separate racks with the layers not exceeding six inches in depth, or stored in crates or boxes not exceeding six inches in depth, or stored as solidly frozen blocks not exceeding six inches in thickness.

Group 2 comprises product in pieces, layers, or within containers, the thickness of which exceeds 6 inches but not 27 inches, and product in containers including tierces, barrels, kegs, and cartons having a thickness not exceeding 27 inches.

If the pork is not described in Table 6.3, the meat must be frozen to a minimum temperature of −30°F in the center.

TABLE 6.3. Freezing Requirements for Trichina-Free Pork[a]

Temperature (°F)	Group 1 days	Group 2 days
5	20	30
−10	10	20
−20	6	12

[a] In accordance with Federal meat inspection regulations.

UNDESIRABLE CONDITIONS

Processed meat products reflect the quality of raw materials used in their manufacture. Aside from meat deterioration due to development of rancidity or microbiological contamination, the suitability of meats for use in manufactured products depends in part on their freedom from the following undesirable conditions: (1) PSE musculature, (2) two-toning, (3) sex odor, and (4) mutton flavor.

Pale, Soft, Watery Pork

Pale, soft, watery or exudative pork, referred to as PSE pork, is a major concern of meat processors. Normal pork is grayish-pink tinged with red in color, firm, and dry. PSE pork is quite pale, soft, and watery. Generally, there is very little evidence of marbling, and muscles are pulled loose from connective tissue attachments. The incidence of PSE pork is related to the following variables:

(1) Season: it is highest when environmental temperatures are high or fluctuating markedly.

(2) Breed of hog: Poland Chinas, Landrace, Hampshires, and Yorkshires are most susceptible. Chester Whites, Durocs, and Berkshires are most resistant.

(3) Sex: slightly higher incidence in gilts than in barrows.

(4) Muscling or lack of fat: highest incidence is in meaty hogs and those with little backfat.

The problem is associated with rapid accumulation of acid in muscular tissues after slaughter, which results in tissues with low pH. Low pH tissues are characteristically light in color, soft, and bind water poorly. Whenever possible, PSE pork should be avoided as a raw material for both sausage and smoked meats. When PSE pork is used for the manufacture of smoked-meat products, such as hams, picnics, and bacon, the end products are usually dry because PSE pork has poor water-binding ability. Cured primals made from PSE pork average 3–5% more shrink in the smokehouse than those made with normal pork. Additionally, when PSE pork is used, the finished products, whether primal or comminuted, will usually be light in color. PSE pork is not a desirable component of comminuted meat products because of its poor ability to bind water and emulsify fat.

Recent evidence has shown that the incidence of PSE pork can be greatly reduced by selection for stress resistance in breeding stock by using the halothane test. In this test, halothane anethesia is administered and only those animals that quickly regain consciousness are retained for breeding purposes. Those animals recovering more slowly are marketed. It has been demonstrated that by using only stress-resistant boars for breeding, the incidence of PSE pork can be quickly reduced.

Dark, Firm and Dry Pork

Dark, firm, and dry pork, a condition referred to as DFD pork, is also a serious problem for meat processors. The DFD condition can be quickly recognized by the extremely dark, dry, and firm appearance of the meat, especially observable in the ribeye or in cross-sections of the ham. Although DFD muscle seems to be the opposite of the PSE condition, it is believed to be closely related. Stress is responsible for both, with PSE pork being the result of stress of relatively short duration. DFD meat, however, is due to stress of a greater duration or intensity, which results in depletion of all or most of the muscle glycogen and lactic acid so that the muscle becomes dark, dry, and firm.

From the standpoint of processors, DFD muscle constitutes a more serious problem than PSE pork because it has a high pH, i.e., pH 5.8 or above. The high pH favors microbial spoilage, which is certainly one of the most serious problems of the industry. DFD pork has been shown to be associated with ham spoilage and development of "glazy" bacon. The latter has been a frequent basis for rejection of exported bacon from Denmark and Holland.

Since both PSE and DFD pork seem to be a manifestation of stress susceptibility of the live pig, they can be simultaneously eliminated by selection using the halothane test. This has already been discussed earlier under PSE pork.

Porcine Stress Syndrome

Another condition, which is closely related to PSE and DFD muscle in pigs, is the porcine stress syndrome or PSS, as it is commonly called.

This condition is characterized by extreme stress susceptibility in live pigs, manifested by trembling and often sudden death. Pigs suffering from PSS frequently die during marketing and/or handling prior to slaughtering. Some packing house employees have become particularly adept at managing susceptible animals so as to avoid any excitement during handling just prior to slaughter. This can greatly reduce the incidence of deaths. PSS can also be eliminated by selection of breeding animals by the halothane test, as explained earlier.

Meat processors are probably not affected directly by the PSS condition unless they are also slaughterers. Indirectly, death losses from pigs suffering from PSS have an effect on meat prices since both meatpackers and swine producers suffer economic losses. Meat from pigs dying from PSS has been described as being even paler in color and more watery than PSE pork.

Two-Toning

Two-toning is associated with muscular tissues of swine. It refers to light and dark color in the same surface or muscle. All primal cuts from pork carcasses can be affected, but the condition is most commonly associated with hams. The normal color of fresh pork is referred to as grayish-pink tinged with red. Pork primals that are too dark are also undesirable, just as are two-toned primals. Pale-colored muscles can be produced by feeding iron-deficient rations to pigs. Both pale and dark colors are associated with pH and the content of myoglobin. High-pH meats are dark in color and have good water-binding and emulsifying properties. On the other hand, low-pH meats are pale in color and have poor water-binding and emulsifying properties. The reason for light and dark colors in the same surface is not known. It may be related to metabolic activity of individual muscles or in the various portions of single muscles. The condition is minimized in cured pork products, but it is present. Two-toning does not appear to affect consumer acceptability for such factors as tenderness, juiciness, and flavor to any marked extent. Its effect is primarily from a visual or aesthetic viewpoint.

Dark Cutting Beef

Dark cutting meat occurs not infrequently in beef. As its name implies, dark cutters have dark-appearing lean muscles that fail to brighten on exposure to the oxygen in air. This condition occurs in about 1–5% of all steer and heifer carcasses, 6–10% of all cows, and 11–15% of young bulls.

The color and pigment changes involved with meat color development are discussed in Chapter 3. Biochemically, dark cutting beef is characterized by having low glycogen reserves and a low reducing sugar content. This causes a high pH of 5.8 or above and is accompanied by a low oxidation reduction potential, which results in low oxygen uptake by the muscles. As in high pH pork, dark cutting beef is more susceptible to spoilage than beef with a normal pH. The high pH also results in a closed structure of intact muscles as a consequence of the imbibition of water by the muscle proteins. This closed structure makes the meat more difficult to cure because it does not readily take up the curing salts, and the high pH favors microbial growth.

Chopping of the meat as is done in manufacturing of sausages facilitates curing and tends to reduce spoilage in high pH meat. However, intact cuts do not readily take up salt, and thus, are more susceptible to spoilage, both because the high pH favors microbial growth and the closed structure of the tissues delays penetration of the curing salts. The same principles also apply to high pH meat, regardless of the species.

Sex Odor

Sex odor refers to the objectionable odor which on occasion emanates from pork when heated. Until recent years, this odor was referred to as boar odor. However, research workers have shown the odor to be associated with barrows, gilts, and sows, as well as with boars and stags. Nonetheless, the incidence has been shown to be much greater in boars than in other classes of swine. Sex odor is present in fat but not in lean tissues. It can be detected when fat is heated to high temperatures, but odor intensity varies from one carcass to another. Federal inspection regulations specify that meat with pronounced sexual odor must be condemned and cannot be used for food products or for rendering. Meat which has less than a pronounced sex odor can be used only in comminuted cooked meat food products, or for rendering. The exact cause of sex odor is unknown, but at least one responsible compound, a steroid, 5α-androst-16-ene-3-one, has been identified. Raw materials suspected of having sex odor can be checked by heating a small sample and sniffing the odor emanating during cooking.

Mutton Flavor

Because of a distinct somewhat strong flavor associated with mutton, meat from mutton carcasses is less marketable than lamb. As with sex odor, there is a wide difference in the ability of people to identify mutton flavor. Although mutton usually contributes highly desirable lean to processed-meat formulations, use should be limited to no more than approximately 20–25% of the total meat block to avoid significant contribution to product flavor. Mutton carcasses are recognized by the round joint on their forelegs, but mutton flesh is distinguished from lamb chiefly by color. Mutton flesh tends to be dark red in contrast to the pink color of lamb. In addition, the texture of mutton is somewhat more coarse. Textural differences may not always be detectable visually. Cause of mutton flavor is not known definitely, but is related to the age of the sheep.

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7

Sectioned and Formed Meat Products

Technically speaking, sectioned and formed meats are restructured products, since they are partially disassembled and then reassembled to form products resembling intact meat cuts. Sectioned and formed meats products differ, however, from restructured products, which are manufactured by flaking or dicing and then reforming. Sectioned and formed products do not utilize grinding, chopping, emulsification, slicing or flaking except for preparation of binders. Sectioned and formed meats are intact muscles or sections of muscles as the major meat component, while the particles of meat are used only as binding substances. Sectioned and formed meats comprise the largest single category of restructured products, from the standpoint of both volume and value. Sectioned and formed meats are discussed in this chapter and other restructured meat products are discussed separately in chapter 15.

CHARACTERISTICS AND IMPORTANCE

Sectioned and formed meat products are prepared from pieces or chunks of meat that are bonded together to form a single fused piece. In other instances, several individual muscles or large pieces of muscle are fused together to give the appearance of being a group muscles from a single cut. The products are processed in a manner that causes them to adhere to each other so that they resemble an intact cut in regard to consistency and appearance. The cohesive substance that binds the pieces or muscles together may be from (1) non-meat additives, (2) meat emulsions, or (3) extractions of myofibrillar proteins derived from the chunks or pieces of meat themselves.

For many years, some boneless hams have been prepared by boning of the fresh raw cuts, forcing them into casings, curing, smoking and/or cooking the final product to cause it to adhere together. Hams produced in this manner would be classified as sectioned and formed products and certainly are not the result of recent processing innovations. Yet the quantity of such hams has never been very large. Devel-

A. M. Pearson et al., *Processed Meats*

opment of sectioned and formed meat products in quantity is of relatively recent origin, with most of the technological advances occurring in the last 20 years. Until recently, the boneless hams produced were not bonded together. Sectioned and formed products, as we think of them today, include a variety of new items, and are generally believed to have originated with the production of turkey rolls and other similar products.

The major advances in producing sectioned and formed meat items can be attributed to the Europeans, who designed tumbling and massaging equipment specifically for production of these products. Most of the modern tumblers and massagers being used today are either imported from Europe or are modifications of European protypes.

Growth in production of sectioned and formed meat products has been extremely rapid. Turkey rolls, roasts, and other sectioned and formed products from turkeys amounted to 665,442,000 lb in 1977. This production utilized some 35% of all turkeys produced. Other sectioned and formed poultry products, mainly from chickens and ducks, comprise a lower percentage of total production than those derived from turkey. Nevertheless, some 2,388,000,000 lb or 20% of all poultry meat from federally inspected plants went into sectioned and formed products in 1977. More than 284,000,000 lb of sectioned and formed hams were also produced under federal inspection in 1977. This accounted for about 19% of all federally inspected hams.

Fresh beef, lamb, veal, and other pork cuts are also being used in production of sectioned and formed products. However, it is difficult to obtain an accurate estimate of the amount of these products being marketed. Some of these products are being shaped like steaks and chops, and may or may not be blade tenderized to improve acceptability. All of these items contribute to the total volume of sectioned and formed meat products, with a greater volume of such products being marketed each year. In addition, new items are still in the developmental stage so that continued growth in the volume and percentage of all meat being used to produce sectioned and formed products seems likely to continue into the foreseeable future.

ADVANTAGES AND DISADVANTAGES

Sectioned and formed meat products have several advantages over intact cuts, which have contributed to their acceptance. (1) They are easier to slice and serve. (2) They are more easily adapted to accurate portion control. (3) They generally have lower cooking losses and higher serving yields than a comparable amount of lean meat from intact cuts. (4) They are nearly always boneless, although some fabricated items may be formed around a single bone, for example, chicken or turkey meat containing a thigh bone. (5) They can be readily molded or shaped to meet a particular demand. (6) Cheaper cuts can be utilized in producing attractive bonded products. (7) The curing process is accelerated, thereby increasing inventory turnover. (8) The color produced is more uniform and easier to control. (9) They can be manufactured so as to resemble higher priced cuts or products, and thus, may offer added economic inducement to processors. (10) Sectioning and forming allows better compositional control, both from the standpoint of amount and distribution of fat.

There are also a number of obvious limitations to producing sectioned and formed meat products, some of which are listed below. (1) Low quality meat is not improved by using in sectioned and formed products. (2) A major investment in equipment is required to produce certain products. (3) Processing requires a high input of both energy and labor. (4) More care must be devoted to development and enforcement of quality control procedures. (5) Special markets must be developed for new products, with emphasis being placed upon promotion and advertising. In spite of the above listed disadvantages, the advantages seem to outweigh them. Thus, there would seem to be opportunities for innovation and growth in production of sectioned and formed meat items.

PRINCIPLES INVOLVED IN PRODUCTION OF SECTIONED AND FORMED MEATS

Three major principles are involved in producing sectioned and formed meat items. (1) A protein–meat surface interaction must be created to form a bond between adjacent pieces or chunks of meat. (2) The meat must be made pliable and soft so that it can be pressed or molded into the desired shape. (3) Heating is necessary to coagulate the proteins so that adjacent pieces of meat or muscles are strongly bonded together. The latter principle is closely related to the first, since the proteins must be available at the meat surface before heating followed by cooling can form a strong junction.

Creating the Surface Protein Matrix

The surface protein matrix can be obtained by using the natural proteins from the meat or by adding non-meat proteins at the surface. The former is generally preferred because the proteins naturally present in the meat form a stronger bond than the added proteins. The bonding of the natural meat proteins is normally produced by salt extraction. The proteins may come from a meat emulsion matrix containing intact chunks or pieces of meat, or from solid pieces of meat that are either tumbled or massaged to extract the proteins and provide the protein matrix.

In order to create a meat–protein surface suitable for bonding, some of the salt-soluble proteins must be extracted. In the emulsion-type matrix, the salt-soluble proteins are mainly provided by the emulsion per se. There may, however, be a small but significant amount of protein released at the surface of the intact pieces of meat during mixing with the meat emulsion. The amount of protein extracted from the pieces of meat will depend not only on the presence of salt, but also on the type of mixer used and the length of mixing. The protein matrix on the surface of the meat will determine the strength of the bond formed during heating.

For products containing only pieces or chunks of meat, tumbling or massaging is commonly used to create the tacky protein exudate at the surface. Salt is also needed to help extract the proteins from the meat. In addition to extracting the myofibrillar proteins so that they accumulate on all surfaces of the pieces of meat, there is some fragmentation of the surface fibers caused by the physical manipulation by the tumbler or massager. The fragments of fibers at the interface between adjacent chunks of meat strengthen the bond between the proteinaceous exudate and the individual pieces of meat. Figure 7.1 shows a light micrograph of the meat exudate and illustrates how the fragmented fibers add strength to the bond between adjacent pieces of meat.

Myosin is the major protein that strengthens the bond between adja-

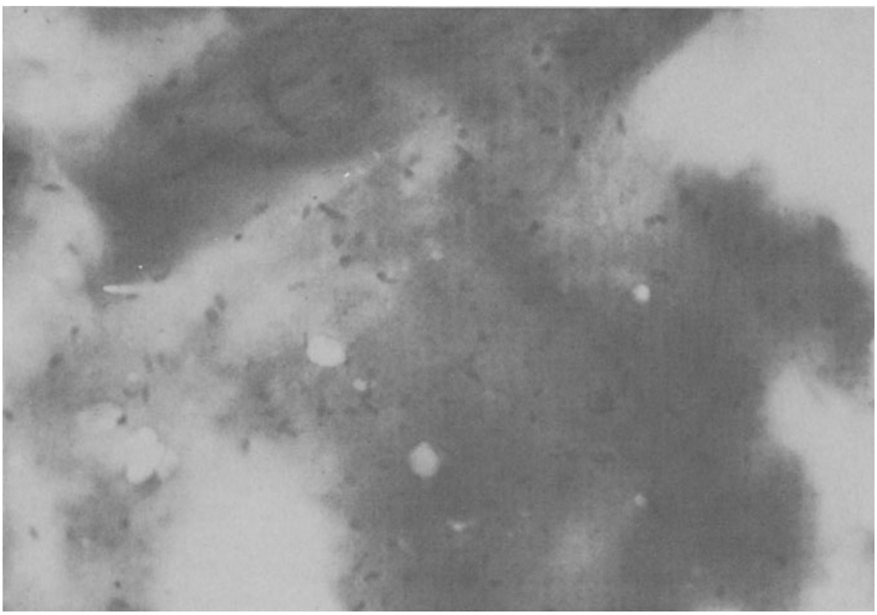


FIG. 7-1. Electron micrograph showing the exudate at the surface of a sectioned and formed ham. Note that the fibers are fragmented and there is an accumulation of a protein matrix, which gives strength at the junction of the pieces of muscle. Courtesy of G. R. Schmidt of Colorado State University.

cent pieces of meat in sectioned and formed products. Actomyosin, actin, and other myofibrillar proteins also appear to have some binding action, but myosin has been shown to form the strongest bond. In fact, the bond formed by myosin makes the junction between adjacent pieces of meat stronger and more difficult to tear apart than the remainder of the meat pieces. This is shown in Fig. 7.2, which illustrates that the bond is stronger than the meat fibers per se. The sarcoplasmic or water-soluble proteins from muscle appear to play only a minor role in binding the meat chunks together.

Non-meat proteins can also be used to bond sectioned and formed items together. In fact, most of the early turkey rolls used non-meat protein sources as binding agents. These included egg white, dried egg albumen, dried skim milk, sodium caseinate, soy protein concentrates and isolates, as well as a number of other proteins. Although all of these proteins have some binding action, the bond is not as strong as that formed by the myofibrillar proteins. However, they generally have two advantages over the natural meat proteins. First, they are lower in price. Second, they can be used to increase the protein content of sectioned and formed products. With the cost of meat proteins continuing to rise, it seems likely that there will be more interest in trying to use these lower priced sources of proteins in sectioned and formed meat products.

Improving Pliability and Shaping of the Product

As previously mentioned, physical manipulation by tumbling or massaging improves the pliability of the product. Once the product

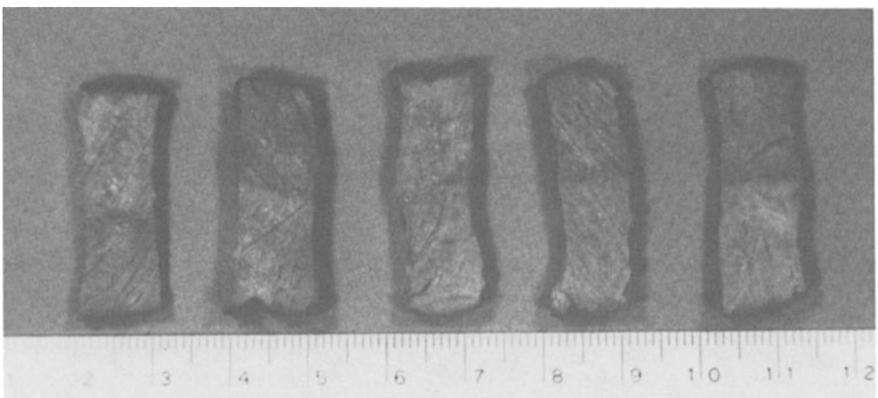


FIG. 7-2. Cores showing the bending of two muscles together in sectioned and formed beef steaks. The bonding between adjacent muscles is stronger than the fibers of the individual muscles so that they will not break at the junction on pulling apart. Courtesy of G. R. Schmidt of Colorado State University.

becomes soft and pliable, it can be shaped and formed. Even more important, however, is the softening of the individual chunks of muscles that is necessary to bring them into close contact with adjacent pieces of meat. The increased pliability is largely due to friction created during mixing, tumbling, and massaging. Even though the tacky protein matrix may be present at the surface of the meat, the pieces must be pliable so that contact with adjacent chunks is complete. Otherwise, there will be interior surfaces of the sectioned and formed items where the union does not occur.

Once the product has become soft and pliable and adequate protein is available on the meat surfaces, it is ready for shaping. Shaping is commonly accomplished by forcing the products into casings or by tying with string. In some cases, the products may be forced into rigid metal containers prior to heating. Regardless of the shaping process, its main function is to force the pieces of meat into close contact so that the bonding process will take place upon heating.

Heating to Stabilize the Bond

Heating is the final step in making sectioned and formed meats. This may be accomplished with heat alone but frequently is combined with smoke application, depending upon the product. The heat causes the tacky exudate to coagulate upon cooling and is responsible for binding the meat together. Although the exact range of effective temperatures has not been experimentally delineated, practical experience indicates that a final internal temperature of 135°–155°F is required. This is the temperature range in which myosin, actin, and most of the other myofibrillar proteins are heat-denatured. Frequently, the time of holding at the final internal temperature is also prolonged in order to destroy microbes on the product and increase its storage life.

Although the heating is usually done by processors, a limited number of products are not heated until just before serving. Such products are generally frozen and distributed in this manner, since they are more perishable than traditionally processed sectioned and formed meat items. Products that are not cooked to a high enough temperature to denature the majority of the myofibrillar proteins also do not bind effectively. Furthermore, the binding action does not become fully affective until the coagulated proteins are cooled. Thus, cooked products that are not fully cooled before serving do not have maximum binding strength.

EQUIPMENT

Formation of the meat–protein matrix is accomplished by one or more of the following procedures: (1) mixing, (2) tumbling, (3) massaging, or (4) ultrasonic treatment. The equipment used for these operations will be discussed briefly.

Mixers

The oldest type of equipment used for producing sectioned and formed meats is the mixer, either with or without vacuum. Mixers are capable of handling small chunks or pieces of meat. Addition of a small amount of ground meat speeds up processing since the ground meat is spread over the chunks and helps to prepare the interface between adjacent pieces of meat for bonding into a continuum. Salt and polyphosphates added before mixing help to extract the soluble protein and form a matrix suitable for binding the pieces together. Mixing also makes the meat soft and pliable so it can be shaped into the desired products.

Mixers are not suitable for large pieces of meat or for intact muscles or muscle strips. The large size and shape does not lend itself to proper mixing. Thus, other methods of creating sectioned and formed meats have been developed to overcome problems encountered in production due to the large size or unusual shape.

Tumblers

Tumblers are the first type of equipment specifically designed to produce sectioned and formed meat products. Tumblers accelerate the extraction of the meat proteins onto the surface of the pieces of meat or the muscle or muscle strips. Salt and phosphate are generally added before tumbling. The action of tumbling not only aids in better extraction of the meat proteins but also improves the speed of curing by increasing salt absorption. Intermittent tumbling has been shown to be more effective than continuous tumbling, although the reason is not readily apparent. It is probable that cure absorption is improved by the loosening of the muscle structure, but there is some evidence that maximum absorption occurs only during the lack of agitation. In other words, agitation tends to counteract the added uptake of cure by the loosened structure of the tissues, and uptake reaches its maximum only when agitation ceases.

Modern tumblers are generally stainless steel drums and are of two types. The side-loaded impact tumblers have baffles similar to cement mixers designed on a pivot so that the angle can be changed to alter the amount of free fall. The multiple batch tumbler is automated so that the drums are completely inverted causing the meat to drop when the drum reaches the apex of its circumscribed movement. Some studies have shown that the meat should drop about 3 feet to obtain the maximum benefit. Both types of tumblers cause the meat to tumble or drop, causing the protein matrix to accumulate on the surface and the meat to become pliable due to the creation of friction during tumbling.

Figure 7.3 shows a side-loaded impact tumbler. These tumblers are designed to operate on a batch basis rather than as a continuous operation. Because tumbling is intermittent, the time required in the tumbler is increased, thus slowing down the flow of product.

A more efficient operation uses a multiple batch type tumbler containing 13 buckets, as shown in Fig. 7.4. A number of stainless steel drums are on a continous chain, so intermittent tumbling is possible without slowing down the operation. Bars and/or needles in the drums cause abrasion of the meat surface and aid in creating a good surface for bonding the pieces of meat together. Furthermore, the abrasion also helps in the uptake of the cure. In addition, modern tumblers often use the built-in needle system for injection of brine into the tumbled products. The intermittent tumbling has also been shown to not only

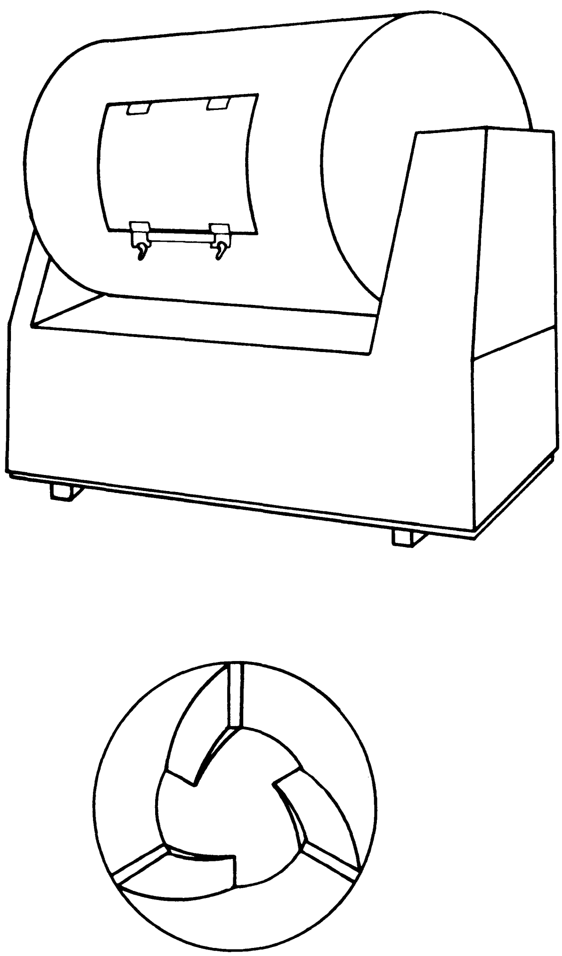


FIG. 7-3. Side-loaded impact tumbler. (Top) Side view of tumbler showing the door and the mechanical power unit with timing device. (Bottom) End view of inside of tumbler showing the baffles, which cause the meat to tumble as it is rotated. Courtesy G. R. Schmidt of Colorado State University.

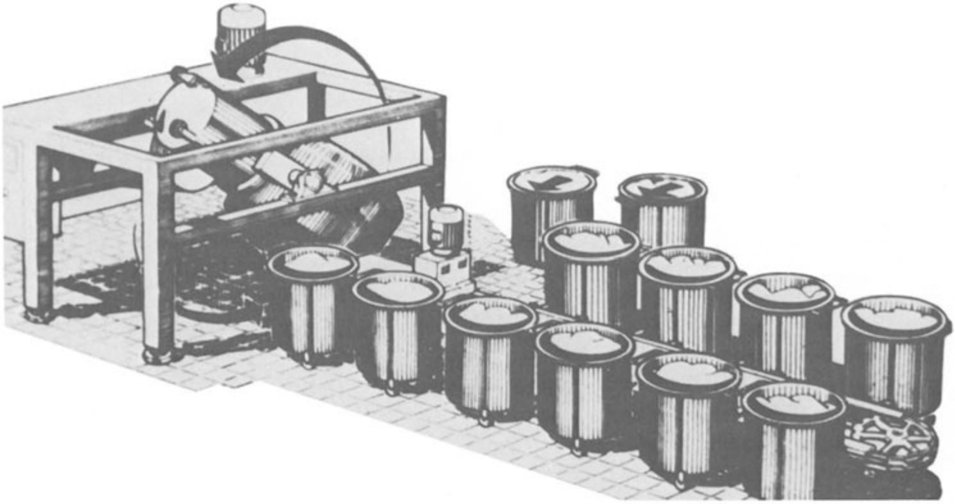


FIG. 7-4. Multiple batch type tumbler with 13 buckets. Courtesy of G. R. Schmidt of Colorado State University.

speed up brine absorption, but increases yields, improves sliceability and decreases cooking losses.

Massagers

Massaging of small pieces of meat can be readily accomplished with a vacuum mixer. Since larger pieces of meat or whole muscles cannot be manipulated with a mixer, commercial equipment exclusively designed for massaging of meat was developed. Thus, massagers represent the second generation of equipment in the production of sectioned and formed meat products. Essentially, a massager is a slow mixer designed to stir or agitate gently large chunks of meat. Massagers are made in a number of different designs with the shape of the blade or propeller being one of the major variations. Another variable is the design of the chamber so that each piece or chunk of meat receives it proportionate share of massaging.

Figure 7.5 shows a schematic diagram of a massager. The massager has the same general advantages and disadvantages as a tumbler. The cure penetration is speeded up by massaging, with intermittent massaging being preferred to continuous operation. The finished product has a greater finished cooked yield. Figure 7.6 shows a sectioned and formed ham made using a massager.

Care should be taken to see that each piece of meat comes into contact with the blade and is properly massaged. Failure of part of a batch to be properly manipulated leads to uneven curing and lower

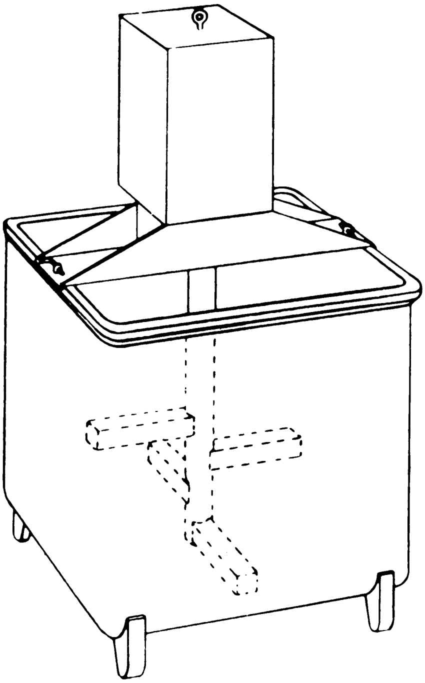


FIG. 7-5. Schematic diagram of a massager. Courtesy G. R. Schmidt of Colorado State University.

yields and poor binding. Since the meat does not fall free as in tumbling, the problem of improper contact is much more common when using massagers.

Ultrasonic Treatment

Low-frequency ultrasound is known to cause tissue disruption. This treatment produces the phenomenon of cavitation, which is the result of bubble or cavity formation in liquids. The collapse of the bubbles results in shock waves that are responsible for damage to the surrounding tissue. Recent research at the University of Illinois has shown that ultrasonic treatment of ham rolls caused changes in the microstructure, increased breaking strength and decreased cooking losses, suggesting that ultrasound can be utilized for producing sectioned and formed meat products.

The exact mechanism of ultrasonic treatment seems to be through disruption of the tissues in essentially the same fashion as with tumbling and massaging. Since only a limited number of studies have been carried out with ultrasonics, the best times and frequencies for operation have not been determined. Although ultrasonics shows promise as a means of preparing the meat surfaces for binding, it is not currently being used on a commercial basis. However, ultrasonics may speed up

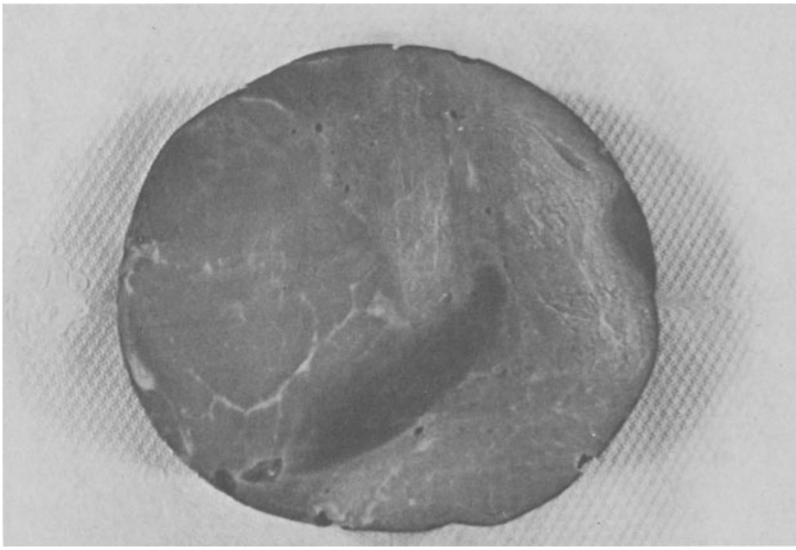


FIG. 7-6. Photograph showing cut through center of sectioned and formed ham showing the continuity of the muscles. Courtesy G. R. Schmidt of Colorado State University.

the process of tissue disruption, increase pliability, and could lead to an on-line process, which would be more energy efficient.

ADDITIVES

The principle additives can be classified by the substances used: (1) curing agents, (2) binding agents, (3) protein additives, and (4) flavoring substances.

Curing Agents

The same substances used for other methods of curing are used in producing sectioned and formed meats, namely, salt, nitrite and/or nitrate. Sugar and/or corn syrup solids are also commonly used in the curing mixture. Since the functions of these curing ingredients are discussed in Chapter 3, they will not be repeated here. Suffice it to say they act in the same way as described earlier, so only their other functions will be considered.

Salt plays another important function in preparation of sectioned and formed meats in that it helps extract the myofibrillar proteins, and thus gives binding strength at the junction between adjacent pieces of meat. The salt also increases the water-binding properties and decreases cooking losses in sectioned and formed meat products. The action of nitrite and/or nitrate is apparently the same as discussed under curing in Chapter 3. The same is also true for sugar and/or corn syrup solids.

The amount of salt added may vary somewhat from product to product, but is generally about 2–2½%. This salt level gives optimum binding. Nitrite is added at a level of 156 ppm. Although nitrates are prohibited in United States, they may be permitted in some other countries. Sugar and/or corn syrup solids are usually added at the same level as used for curing hams.

The cure is normally added prior to manipulation, since agitation produced by tumbling or massaging speeds up the penetration of the cure. As already pointed out, the cure is absorbed more readily during intermittent manipulation.

Binding Agents

There are actually two distinctive types of binding agents: (1) those that enhance the binding of adjacent pieces of meat together, and (2) those that increase the water-binding capacity of the finished product. Fortunately, polyphosphates, which are commonly added to sectioned and formed products, combine both types of binding properties. Polyphosphates are added to many sectioned and formed meat products at a level of about 0.5%. They are added before manipulation of the meat. There appear to be distinct advantages to intermittent tumbling or massaging in regard to binding strength and increased yields, both of which are enhanced by polyphosphates.

A number of protein additives are frequently added to sectioned and formed meat products, including raw egg white, dried egg albumen, nonfat dried milk, sodium caseinate, soy protein concentrates and isolates. This has been discussed earlier in considering formation of the protein binding matrix. Others, such as food grade blood proteins, may also be added, being common additions in some European countries. These protein sources are low in cost in relation to meat and are commonly added to increase the protein content. They appear to exert their binding action through gel formation rather than by direct interaction with the muscle proteins of the meat pieces.

SELECTION OF RAW MATERIALS

Use of high quality raw products is an important consideration in production of sectioned and formed meats. As already pointed out, the quality of the products produced is no better than that of the meat utilized for its production. Thus, several considerations are essential in selecting raw materials: (1) only sound meat of good microbiological quality should be used; (2) cuts high in connective tissue should be avoided; (3) excess fat on the meat gives an unattractive product; and (4) cure, seasoning, and other additives should be of high quality.

Meat that is not microbiologically sound should not be used in production of sectioned and formed products. If the microbiological count is abnormally high, spoilage may ensue during processing. Since chunks and pieces of meat are used and are agitated together by mixing, tumbling, or massaging, contamination of any piece by bacteria will affect the remainder of the meat, increasing the chances for spoilage. The meat should be freshly prepared and processed without any undue delay or flavor problems may develop during preparation. Failure to use sound fresh meat and to proceed rapidly with processing may result in a final product of inferior quality.

Connective tissue is still evident following processing. Furthermore, connective tissue on the surface of the cuts prevents good extraction of myosin and the other myofibrillar proteins. Connective tissue proteins also have poor binding properties and produce products that fail to hold together after processing. Thus, careful selection of meat relatively low in connective tissue is an essential step in production of high quality sectioned and formed meats.

Meat selected for use in producing sectioned and formed products should be low in fat. Large deposits of fat become even more evident after processing and make the products unattractive. In addition, excess surface fat on the chunks of meat minimizes protein extraction and results in poor binding with adjacent fat or lean tissues. Selection of meat low in fat and trimming of excessive fat from the meat is an important step, which adds to the attractiveness of sectioned and formed meats. The significance of this step in producing attractive products that are in high demand should not be overlooked.

Only high quality curing ingredients or seasoning should be added. Contaminated spices or seasonings of poor quality can greatly detract from the acceptability of an otherwise high quality sectioned and formed product. It is advisable to deal only with reputable suppliers who can offer not only good quality additives, but also assist processors in developing new products or in trouble shooting. The extra services and advice available by suppliers is much more valuable than the limited savings obtained by purchasing from the cheapest available source.

TYPES OF PRODUCTS

Poultry Products

Turkey rolls are a major item. They may be produced from either breast meat, thigh meat or by combining both dark and light meat in a single product. Chickens and ducks may also be made into sectioned and formed products, but usually are smaller in size than turkey rolls.

Some of these products are of individual serving sizes, which are in demand by airlines and other fast service food vendors. Poultry products of individual serving size often have a bone bonded to the meat to make them resemble an intact chicken thigh. However, boneless products are much more common and may resemble the entire boneless bird.

Pork Products

Boneless sectioned and formed ham products are common items in commerce. They may be shaped like the original ham or may be forced into casings or molds of various shapes. Generally, they are oblong, round or square after shaping. They may be prepared in casings or as canned products (see Fig. 7.7). Some muscles from the pork shoulder or the picnic may be removed and used in producing sectioned and formed products similar to hams. The loineye muscle may also be removed from heavy sow carcasses and used for producing sectioned and formed meats.

Beef and Veal Products

Beef and veal muscles may be removed in their entirety and used in producing sectioned and formed items. The muscles of the round or leg,

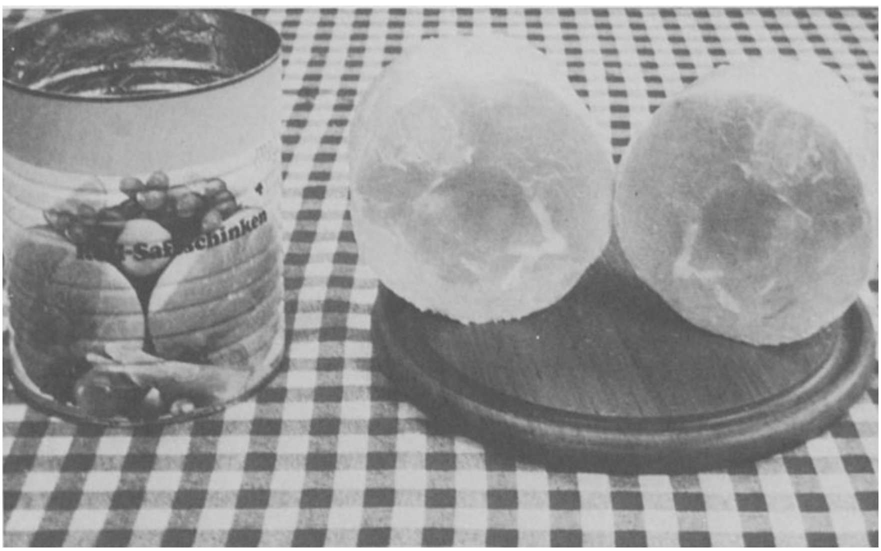


FIG. 7-7. Photograph showing a canned ham sliced through the center to show how the muscles are bonded to each other. Courtesy G. R. Schmidt of Colorado State University.

especially the eye of round muscle is used for this purpose. The large muscles of the chuck, except for the shoulder clod, which has too much connective tissue, can also be used for processing into sectioned and formed products. These muscles or cuts are commonly taken from cow carcasses of cutter and canner grades and either cut into chunks or the entire muscle may be used for sectioned and formed products. Leanness and freedom from large deposits of connective tissue are important considerations in their selection.

SECTIONED AND FORMED MEAT FORMULATIONS

Formulations for a number of sectioned and formed products are included below. These products are only examples, as many different items can be produced by this technology.

Sectioned and Formed Ham

Ingredients Boneless ham rolls are prepared from good quality freshly boned hams or ham pieces. The hams may be used fresh or after freezing and thawing. Freezing followed by thawing will result in more protein extraction and more fiber disruption, which produces greater binding strength. The brine ingredients needed to prepare a brine for pumping at 16 or 32% are given below. The amount of salt in the brine is calculated to give 2.25% salt in the finished ham. This amount will vary somewhat depending on the method of smoking and cooking.

Pickle Formula[1]

Ingredients	*Brine for 16% pump (lb)*	*Brine for 32% pump (lb)*
Salt	13.00	7.03
Sugar	4.87	2.63
Phosphate	1.62	0.88
Ascorbate	0.36	0.19
Nitrite	0.10	0.05
Water	80.05	89.22

[1]From Zapata (1981).

Trimming and Cutting. Excess surface fat and seam fat should be removed during preparation. Any tendons or sinews should be removed. Large muscles should be split lengthwise to facilitate curing and shaping.

Processing. The brine and ham pieces are added to the tumbler. The tumbler is operated on an intermittent cycle for 18 hours to give 15 minutes tumbling and 45 minutes off during each one hour period. By the end of 18 hours all of the brine should be absorbed.

Stuffing. Following massaging or tumbling, the meat is stuffed into fibrous cellulose casings of 12.5 cm. The pieces of meat should be tightly stuffed to force the chunks of meat together so that they will bind during heating.

Cooking and Smoking. The rolls are then cooked and smoked (if desired). A suggested smokehouse schedule normally requiring about 12 hr for cooking and/or smoking is shown in Table 7.1. The amount of smoke may vary from none to heavy, depending on market preferences.

Cooling. The sectioned and formed hams are chilled to about 34°F before marketing. They may be marketed as whole pieces, cut into smaller sections or sliced and vacuum packaged. Demand for these sectioned and formed products is good.

TABLE 7.1. Smokehouse Cooking Schedule for Sectioned and Formed Boneless Hams

Time (hr)	Temperature (°F)		Relative humidity (%)
	Dry bulb	Wet bulb	
2	140	122	40
6	160	128	40
4[a]	176	142	40

Source: Zapata (1981).

[a] At the end of the smoking process the internal temperature of the finished hams should reach approximately 155°F (68°C).

Beef Rolls

Ingredients. Use fresh lean beef trimmings. The fat content should be not more than 12%. Curing ingredients are salt of food grade at a level of about 2½%; tripolyphosphate at a level of 0.25%; and nitrite at a level of 156 ppm. All curing ingredients are then dissolved in 8% water by weight.

Preparation. The beef trimmings are ground through 1-in. plate. The cure and phosphate in water is added to the meat and mixed in a meat mixer for a minimum of 20 min. The temperature of the meat should be maintained at 34°F during all phases of preparation and mixing. All of the curing ingredients should be taken up during mixing.

Stuffing. At the end of mixing, the meat is removed from the mixer and placed in the stuffer. It is then stuffed into moisture-proof fibrous casings using the large horn at a line pressure of 35 to 70 psi.

Cooking and Cooling. The rolls are then placed in a water cooker at 185°F and held at this temperature until the internal temperature of the rolls reaches 158°F. After cooking, the rolls are immediately cooled to 34°F and held. The product can be sold as intact pieces, cut into smaller sections or sliced and vacuum packaged.

Combination Ham–Soy Protein Isolate Product (66% Ham)

Ingredients. Freshly boned hams should be skinned and all external fat removed. The hams should then be separated into individual muscles by separating along the natural seams. Water, soy protein isolate (label should list soy protein isolate, magnesium sulfate, zinc sulfate, niacinamide, ferrous sulfate, vitamin A acetate, calcium pantothenate, thiamine mononitrite, copper sulfate, pyridoxine hydrochloride, riboflavin and vitamin B_{12}), salt, sugar, sodium tripolyphosphate, sodium erythorbate, sodium nitrite, and flavorings are all needed for production of the product. The pickle is made up as shown below. Pickles for combination meat products of different composition are given in Table 7.2.

Pickle Formula

Ingredients	*lb*	*oz*
Water	80.4	
Salt	6.6	
Sugar	1.1	
Sodium tripolyphosphate	0.8	
Soy protein isolate	11.0	
Sodium nitrite		0.5
Sodium erythorbate		1.6

Processing. The ham muscles are pumped with the pickle using a multineedle injector. Add as near to 55% by weight as possible. Transfer the muscles to a massager and add the remaining pickle to bring to 55% by weight. Alternate massaging and stopping as necessary until all the pickling fluid is absorbed and appears to be well distributed. This will require about 24 hr.

TABLE 7.2. Different Pickle Formulas for Products Containing Added Soy Protein Isolates to Achieve Different Final Composition[a]

	Meat analysis								
	Up to 7% fat, 20% protein			8–12% fat, 19% protein			13–17% fat, 18% protein		
Formula number	1	2	3	4	5	6	7	8	9
Water	81.3	80.5	80.0	81.1	80.4	79.9	79.9	79.9	79.7
Soy protein isolate	8.8	10.9	12.3	8.9	11.0	12.5	10.1	11.5	12.6
Polyphosphates	1.0	0.8	0.7	1.0	0.8	0.7	1.0	0.8	0.7
Sugar	1.2	1.1	1.0	1.2	1.1	1.0	1.2	1.1	1.0
Sodium chloride	7.6	6.6	5.9	7.6	6.6	5.9	7.6	6.6	5.9
Sodium nitrite	0.5 oz	0.5 oz	0.4 oz	0.5 oz	0.5 oz	0.4 oz	0.5 oz	0.5 oz	0.4 oz
Sodium erythorbate	1.9 oz	1.6 oz	1.3 oz	1.9 oz	1.6 oz	1.3 oz	1.9 oz	1.6 oz	1.3 oz
Extension level with soy protein	44.4%	55.5%	66.7%	44.4%	55.5%	66.7%	44.4%	55.5%	66.7%
Yield (10% processing shrink)	130%	140%	150%	130%	140%	150%	130%	140%	150%

[a] Amounts given in pounds except as otherwise noted.

Brine preparation:
1. Disperse soy protein isolate in water using a high speed mixer. Mixing time 15 minutes after wetting.
2. Add sugar.
3. Add polyphosphates and mix until dissolved.
4. Add sodium chloride and mix approximately 10 minutes.
5. Add sodium nitrite and sodium erythorbate and mix.

Stuffing. Stuff into 12.5 cm fibrous cellulose casings.

Cooking and Cooling. Cook in a smokehouse at a temperature of 170°F and a relative humidity of 40% until the product reaches an internal temperature of 152°F. Light smoke may be applied if desired. Hams should be chilled and held at 34°F until marketed.

Combination Corned Beef–Soy Protein Isolate Product (70% Corned Beef)

Ingredients. Boned and trimmed fresh beef chunks are prepared from beef rounds or chucks, with excess fat and connective tissue being removed. Soy protein isolate (see page 139 for labeling requirements) and other ingredients are made into a pickle as shown below.

Pickle Formula

Ingredients	*lb*	*oz*
Water	82	
Salt	7	9.6
Soy protein isolate	10	
Sodium erythorbate		1.75
Sodium nitrite		0.60
Flavorings (corned beef spices)		4.5

Processing. The beef chunks are injected with 45% by weight of the pickle using a multineedle injector. The meat and remaining pickle to make up 45% by weight are added to a massager. Massage using the discontinuous cycle until all of the pickle is absorbed. This normally requires 20 to 24 hr.

Cooking and Cooling. Cook in hot water at 180°F or in a smokehouse with steam until the internal temperature reaches 160°F. Package as for regular corned beef. Cool to 34°F and hold under refrigeration until reheated for serving.

Combination Roast Beef–Soy Protein Isolate Product (70% Roast Beef)

Ingredients. Lean cow chucks are boned, and excess fat and connective tissues removed. A brine is prepared from water, the ingredients shown below, and flavoring material.

Pickle Formula

Ingredients	*lb*
Water	79.4
Salt	6.1
Dextrose	1.3
Sodium tripolyphosphate	1.0
Soy protein isolate	12.2

Processing. Grind the meat coarsely to form 2-in. cubes. The ground meat is transferred to the mixer and pickle is added to 40% by weight. The mixer is started and mixing continues until all of the brine is absorbed. The temperature should be kept below 34°F during mixing. A total mixing time of 30 min to 1 hr is normally required for complete absorption of the brine.

Stuffing. The finished mixture is stuffed into fibrous cellulose casings.

Cooking and Cooling. Cooking is carried out in a 185°F oven until the internal temperature of the product reaches 164°F. The cooked product is then chilled to 36°F. For holding, the product should be frozen and stored at 0°F.

Alternate Method for Beef–Soy Protein Isolate Product (70% Roast Beef)

An alternate procedure for preparing the same product does not grind the beef but uses intact chunks of meat. The brine (shown below) also differs slightly. In addition, the brine is injected into the chunks of meat by adding 45% by weight with a multineedle injector. In this case, the meat is placed in the massager along with any excess brine and massaged until all of the brine is absorbed. Massaging requires 20–24 hr. Cooking and packaging follows the same procedure.

Pickle Formula

Ingredients	*lb*	*oz*
Water	115	
Soy protein isolate	15.25	
Tripolyphosphate	1	2
Salt	8.25	

Brine Preparation. Weigh out 100 lb of water. Add the soy protein isolate slowly while mixing at high speed. Mixing is continued for 15 min after the last soy protein isolate is dissolved. Dissolve the tripolyphosphate in 15 lb of hot water. Add and continue mixing. Add the salt and mix until dissolved, which takes about another 10 minutes.

Stuffing. Stuff into fibrous cellulose casings.

Cooking and Cooling. Cooking is carried out at 185°F in an oven until the temperature reaches 164°F internal. Chill to 36°F. For holding, freeze and store at 0°F.

Combination Roast Turkey Breast–Soy Protein Isolate Product (66% Turkey Breast)

Ingredients. Boneless turkey breasts and a brine, comprising flavorings, and the ingredients listed below are used. See page 139 for the labeling requirements for soy protein isolate.

Pickle Formula

Ingredients	*lb*
Water	81.5
Salt	4.0
Dextrose	1.0
Sodium tripolyphosphate	1.0
Soy protein isolate	12.5

Processing. Grind the turkey breast into 2-in. chunks. Remove all skin and sinews. Transfer the turkey breast meat to a mixer and add brine to 50% by weight. Mix until all of the brine is absorbed. This usually requires 15–45 min.

Stuffing. Stuff into fibrous cellulose casings.

Cooking and Cooling. Cook in an oven at 185°F until the internal product temperature reaches 164°F. Chill to 34°F and then freeze at 0°F.

Cooked Veal Rolls

Ingredients. Veal rib eyes, shoulder clods, or other cuts high in lean content may be used. Cuts having 85 to 95% lean should comprise at least 75% of the mixture. Veal trimmings containing not less than 60% lean are used for preparing the binder and should comprise approximately 25% (but no more) of the mixture. Salt 1–2% depending on preference; phosphate, 8 oz dissolved in 1 lb of water per 100 lb total meat (maximum legal limit of 0.5%); other seasonings as desired.

Trimming and Cutting. Tendons and excess fat should be removed.

Preparation. The veal trimmings are chopped coarsely or else ground through a ⅛ to ¼-in. plate. Add 5 to 10% water if desired. This forms the binder for the larger pieces of veal. The chunks of veal (85 to 95% lean) are ground through a 1- to 2-in. plate. This portion should comprise at least 75% of the total mixture. Place the lean veal trimmings (binder) and the veal chunks together in a mixer. Start the mixer and add seasonings and phosphate solution. Mix thoroughly. Then the mixture should be vacuum-mixed for 4 min or until it is tacky and sticks to the fingers when handled. Vacuum mixing produces a roll with fewer internal air pockets or spaces and results in a smoother surface and permits better portion control. Use the maximum vacuum obtainable, normally about 28 in.

Although larger chunks can be used in making veal rolls, the smaller size given here gives a more uniform color. Larger pieces take longer to cook than the binder, resulting in a gradation in color. The binder is not necessary to prepare veal rolls, but it fills any voids and permits better portion control. The binder also gives a smoother surface and 1–2% better cooking yields.

Stuffing. The meat-binder mixture is stuffed in the desired type and size fibrous casing by means of press, air stuffer, or other suitable equipment. Vacuum stuffing provides some of the advantages of vacuum mixing.

Cooking. If water-cooking is employed, a moistureproof fibrous casing should be used, usually a No. 8 or 9 size. Veal loaf can be processed by water-cooking or by dry-processing.

Veal rolls can be cooked in forced-air convection ovens, smokehouses, or equivalent equipment at temperatures up to 350°F. The rolls can be cooked in either moistureproof or conventional fibrous casings. However, browning does not occur in moistureproof casings. Blanching for 5 to 10 min in 190°F water or in the dry-processing equipment will make it possible to remove the moistureproof casing

TABLE 7.3. Cooking Time for Veal Rolls in No. 9 Fibrous Casings

Cooking method	Cooking temperature (°F)	Cooking time to internal temp. of 140°F		145°F		150°F	
		hr	min	hr	min	hr	min
Water or steam	160	2	30	2	50	3	25
	150	2	30	4	20	—	—
	145	5	—	—	—	—	—
Oven	250	3	—	3	15	3	30

without the roll falling apart. Removal of the casing will allow browning to occur during the later phases of cooking. The rolls in either type of casing can be cooked from the frozen state, but require longer cooking times. The cooking times for a No. 9 fibrous casing are shown in Table 7.3.

Cooked Beef Rolls

Ingredients. Beef rounds, knuckles, or sirloin butts of 85 or 95% lean comprise the basic meat ingredients. Beef trimmings of 60% or more lean are used as a binder, in combination with phosphates and seasoning. The binder (trimmings) should not constitute over 25% of the total meat block, while the beef rounds or sirloin butts should comprise at least 75% of the total. A phosphate-water solution (8 oz phosphate in 1 to 1½ lb water for every 100 lb of meat) and 1 to 2% salt (according to taste) are also included.

Trimming and Cutting. Tendons and undesired fat should be trimmed from the rounds, knuckles, or butts. The high-quality trimmings should be kept and cut into small pieces, while the undesirable portions should be discarded. Table 7.4 shows the approximate yields for different types and grades of meat prepared for cooked beef rolls.

Preparation. Boneless beef rounds, knuckles, or butts are passed through a 1- to 2-in. grinder plate. This portion should not be less than 75% of the total meat block. The binder is prepared by chopping the lean trimmings (60% lean) coarsely, or by passing through a ⅛- to ¼-in. grinder plate. Between 5 and 10% water should be added during chopping or grinding. The binder should be limited to a maximum of 25% of the total meat.

The ground chunks and the ground trimmings (binder) are placed in

TABLE 7.4. Yields and Trim Losses for Various Cuts and Grades of Beef Prepared for Cooked Beef Rolls

Cut and grade of meat	Yield[a] (%)
Inside cow rounds, U.S. Utility or Cutter	86
Outside cow rounds, U.S. Utility or Cutter	84
Inside rounds, U.S. Choice	70
Outside rounds, U.S. Choice	70
Knuckles, U.S. Utility or Cutter	90
Sirloin butts, U.S. Utility or Cutter	76
Sirloin butts, U.S. Choice	63

[a] Proportion of the cut that is available after removing the fat, bone, and tendons.

a mixer and blended with the seasonings. Federal regulations limit the level of phosphate to 0.5% of the total meat weight. After the salt and phosphates are thoroughly dispersed, the blend should be vacuum-mixed for 4 additional min. The mixture will be tacky and will stick to the fingers when handled. The efficiency of the mixer may slightly alter mixing times. Although vacuum mixing and the use of small chunks of meat (1- to 2-in. pieces) are not absolutely necessary, better portion control and appearance will result from their use. Similarly, the binder is not essential, but in its absence there are void spaces and portion control is more difficult.

Stuffing and Pressure Packing. The meat and binder mixture is stuffed into the desired type and size of fibrous casing, using a press, air stuffer, or other suitable equipment. Vacuum stuffers provide some of the advantages of vacuum mixers. The rolls should be packed to the recommended sizes for the casings.

Cooking. Cooked beef rolls can be processed by either water-cooking or dry-processing. Water-cooking should be done only in moistureproof fibrous casings. Usually No. 8 or 9 casings are used. The water temperature is usually 10°F higher than the desired internal temperature of the meat, which is usually 140°–150°F. Table 7.3 shows a schedule of times and cooking temperatures required to produce different degrees of doneness.

Dry-processing of beef rolls can be carried out in forced-air convection ovens, smokehouses, or equivalent equipment at temperatures up to 350°F. The rolls can be cooked in moistureproof or conventional fibrous casings. However, browning will not take place in moistureproof casings.

The moistureproof fibrous casings can be removed by soaking the rolls for 5 to 10 min in 190°F water. Once the casings are removed, browning will take place on heating. Rolls in either type of casing can be cooked from the frozen state, but require more time for cooking.

Water-cooked rolls can be cooled by showering with cold water or in slush ice. They should be cooled to 100°F or below, and may then be frozen or stored at 32°–38°F. Dry-processed rolls may be cooled at room temperature or by placing in a cooler at 40°F until the internal temperature is less than 100°F. After cooking, the product in fibrous casings should be placed in polyethylene sheets to prevent moisture losses during freezing or refrigeration. Moistureproof fibrous casings may be frozen or refrigerated without additional packaging.

Smoked, Chopped Turkey Loaf

Ingredients. All-white meat and all-dark meat turkey rolls are made from boneless turkey breast and boneless turkey thighs, respectively. Both contain the respective kinds of turkey skin and broth.

Smoked, Chopped Turkey Loaf

	White Meat		Dark Meat	
Ingredients	*lb*	*oz*	*lb*	*oz*
Turkey breast meat	88			
Turkey thigh meat			88	
Defatted turkey broth	15		15	
Turkey skin	12		12	
Sodium caseinate	3	8	3	8
Chicken roll seasoning	1	4	1	4
Monosodium glutamate		8		8
Sodium nitrite		1/8		1/8

Preparation. Whole eviscerated frozen tom turkeys weighing 20–24 lb are thawed and boned. The skin is removed. Only the breast meat, thigh meat, and skin are used. The yield on eviscerated weights should be approximately 54%. One half of the breast meat or thigh meat is left intact and placed in the following pickle for 16 hr at 40°F.

Pickle Formula

Ingredients	*gal*	*lb*
Water	100	
Salt		52
Phosphate		35
Nitrite		1

The pickled meat is removed from the phosphate solution, allowed to drain well, and ground through a 1-inch plate. After grinding, the pickled meat is set aside until needed.

The turkey skin and 1 lb defatted broth are chopped together into a smooth paste. The remaining portion of the unpickled meat, either white or dark, is then added to the chopper along with the remainder of the broth, caseinate, and spice. It is then chopped until it is smooth in consistency. The finished emulsion is then transferred to a mixer along with the coarse-ground pickled meat and blended.

Stuffing. The mixture is stuffed into No. 8 × 28 in. fibrous casings using a conventional pneumatic stuffer at 80 lb line pressure. The stuffed casings are placed in 3⅞ × 3⅜ in. wire cages and compressed into squares. Unpressed casings may be used if a round shape is acceptable.

Smoking. The wire cages or unpressed product are suspended from smokesticks and processed in an air-conditioned smokehouse. The following schedule is suggested:

Time (min)	*House Temperature (°F)*	*Relative Humidity (%)*	*Smoke Added*
15	140	40	yes
15	150	40	yes
15	160	40	yes
15	170	40	yes
120	180	80	yes
60	190	95	no

The smoking process requires a total of 4 hr, and the internal temperature of the product should be 170°F at the end. After processing, the rolls should be chilled in cold water for 45 min or placed in cooler storage at 40°F for 16 hr. The chilled product is removed from the cages and the casings are stripped off before slicing.

Process-storage shrinkage amounts to approximately 6.5–8%. In some areas, products of this type are packaged for commercial sale in 3-oz packets, containing 14 to 20 slices each. White-meat rolls sell at a somewhat higher price than dark-meat rolls.

Turkey Roll

Ingredients. Boneless, skinless turkey meat (either white or dark meat) and an emulsion made from body skins, wing meat, and wing skin. Part of the emulsion can be replaced by a binder made of soy protein concentrate and sodium caseinate. The binder may replace a maximum level of 3½% of the meat and skin weight.

Turkey Roll

Ingredients	*lb*	*oz*
Turkey meat, boneless and skinless (white or dark)	90	
Emulsion or binder	10	
Salt	1	8
Prepared seasoning	1	8
Phosphate		8

Emulsion Preparation. Grind skins (body and wing skins) and wing meat through a ⅜-in. plate; then put them through a 1.7 mm plate in a Mincemaster or chop into a fine emulsion. If an all-dark-meat roll is prepared, one can use automatically deboned turkey meat or emulsified dark meat in the emulsion. This will prevent a grainy appearance, which occurs if emulsified skins are used in dark-meat emulsion rolls.

Meat Preparation. Tendons and blood vessels are removed. The remainder of the meat is cut into the desired size pieces. Place meat in mixer and add a phosphate slurry (composed of 1 part phosphate and 3 parts water). Add salt and continue mixing until the meat becomes tacky. Add the skin emulsion, seasoning, and binder. Continue mixing for 1 to 2 additional min.

Stuffing. Stuff into moistureproof or conventional fibrous casings with a pneumatic stuffer. Pressure-pack on conventional closing equipment. A combination white and dark meat roll can be prepared by layering alternate white and dark meat portions to give both white and dark meat in each slice.

Cooking. Rolls can be cooked in 180°F water to an internal temperature of at least 160°F. Cooking time is about 2½ hr in a No. 6 fibrous casing. Rolls should be cooled in cold running water for approximately 15 min and then be placed in slush ice overnight. They can be frozen the following day.

Rolls can be dry-roasted in conventional fibrous casings. They are cooked in a 300°F rotary oven or smokehouse to an internal temperature of 160°F. To ensure complete browning, the rolls should be rotated once or twice during cooking. They are chilled the same as water-cooked rolls.

Turkey Ham

Ingredients. Boneless, skinless turkey thigh meat and automatically deboned turkey meat is used.

The pickle is composed of the following ingredients and amounts:

Pickle Formula

Ingredients	*lb*	*oz*	*gal*
Water			100
Phosphate	50		
Salt	12	8	
Erythorbate	3		
Nitrite	2		

Ten gallons of pickle will cover 225 lb meat, 25 gal 550 lb, and 50 and 100 gal 1,200 and 2,500 lb meat, respectively. The gain in weight while in the pickle falls within a range of 7 to 10%.

Trimming. Boneless thigh meat is trimmed of excess fat, blood vessels, and tendons.

Processing. Place in the curing pickle for a maximum of 24 hr at 40°F. After curing, remove the thigh meat from the pickle and drain for 5 min. Place in mixer, add 1% salt and continue mixing until the meat becomes tacky. Add 20% of deboned meat and seasonings as desired. Mixing is continued for an additional 1 to 2 min. Total mixing time will depend on the efficiency of the mixer.

Stuffing. The mixture is stuffed into prestuck fibrous casings using a conventional pneumatic stuffer or other suitable stuffing equipment. The product is pressure-packed on conventional closing equipment and placed on flat ham screens.

Smoking. The product is placed on a smokehouse tree, put in an air-conditioned smokehouse, and processed as follows:

Temperature (°F)	*Relative Humidity (%)*	*Time (min)*
Cold smoke (about 100)	—	5
140 to 180	40	60
180	40	To 155°F internal temperature or above

Total time in the smokehouse depends on the size of casing, but the internal product temperature should reach at least 155°F. The smoked product should be chilled in a cold-water shower for 30–45 min and then be placed in a 40°F cooler overnight. The casing is then removed and the product sliced. An 80–90% yield can be expected after processing.

Turkey White Meat–Turkey Ham Combination Roll

Ingredients. The product is composed of two layers, one of turkey white meat and an emulsion made from body skins, wing meat, and wing skin. A binder composed of soy protein concentrate and sodium

Turkey Combination Roll

Ingredients	*lb*	*oz*
Turkey white meat, boneless and skinless	90	
Skin emulsion	10	
Salt	1	8
Prepared seasoning	1	8
Phosphate		8

caseinate may be mixed with the skin emulsion to the extent of 3½% of the weight of the meat and skin. The turkey ham is composed of cured turkey thigh meat and automatically deboned turkey meat.

Emulsion Preparation. Pass the skins (body and/or wing) and wing meat through a ⅜-in. grinder plate. Chop to a fine emulsion or put through a 1.7-mm plate of a Mincemaster.

Meat Preparation. Trim the white meat free of tendons, blood vessels, and excess fat. Cut into desired size pieces. Place meat in mixer, add phosphate slurry (1 part phosphate to 3 parts water) and begin mixing. Add salt and mix until surface becomes tacky. Add emulsion, seasoning, and binder. Continue mixing for an additional 1 to 2 min.

Prepare turkey ham from whole thigh meat as described in the previous formulation. After the thigh meat is cured and mixed, and 20% of deboned turkey meat added and mixed, the turkey ham is ready for stuffing.

Stuffing. The turkey white meat and the turkey ham are stuffed into fibrous casings to give two distinct layers. A half-shell horn or other suitable equipment places a layer of turkey white meat and a layer of turkey ham in each slice. Plans for constructing a half-shell horn are shown in Fig. 7.8. The product is pressure-packed and closed with conventional equipment.

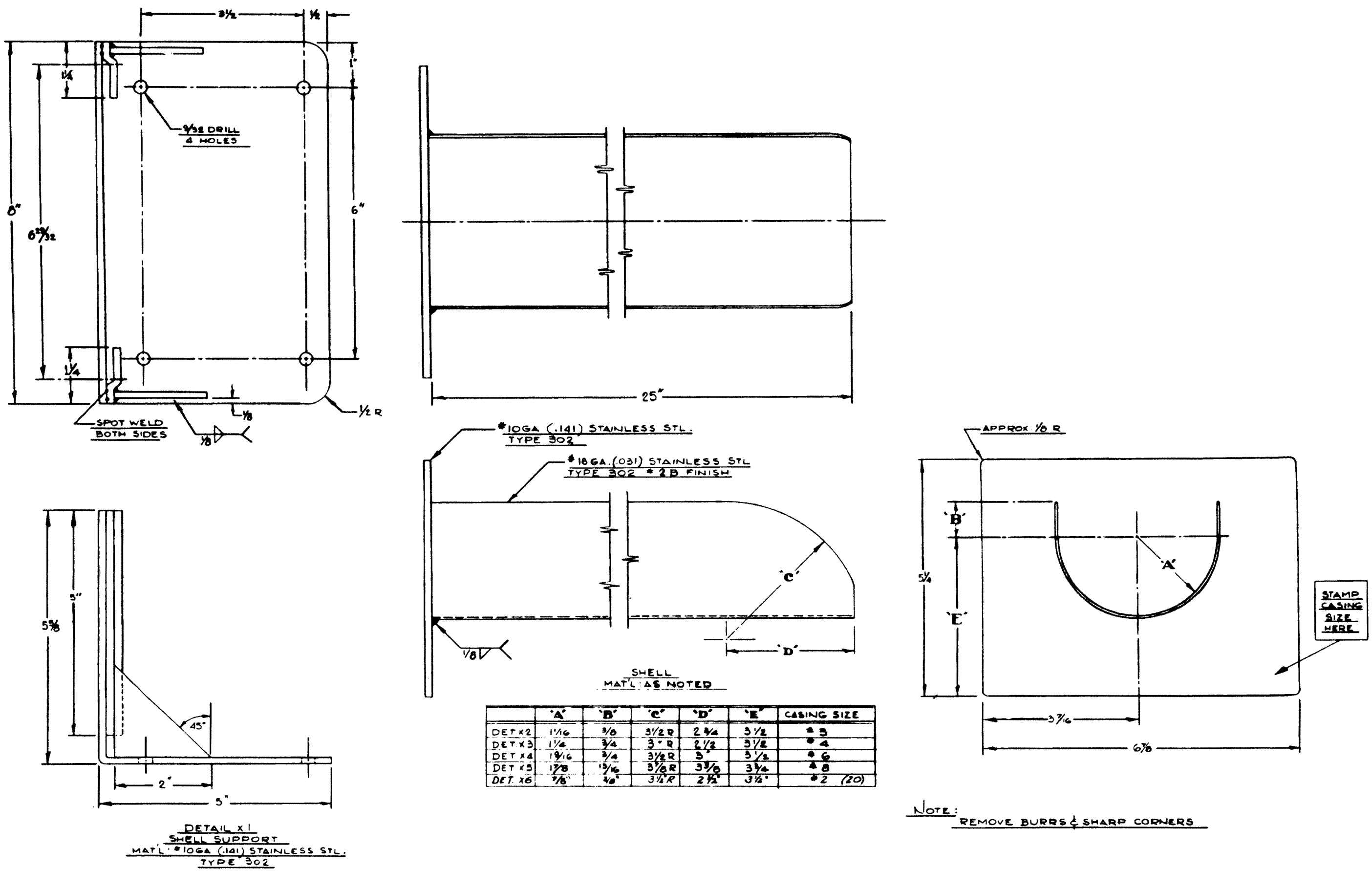
Smoking. The rolls are placed on a smokehouse tree, put into an air-conditioned smokehouse and processed as follows:

Temperature (°F)	*Relative Humidity (%)*	*Time (min)*
Cold smoke (not over 100)	—	5
140 to 180	40	60
180	40	To at least 155°F internal temperature

Total cooking time depends on the casing size, but should result in an internal temperature of at least 155°F. The processed product is chilled in a cold-water shower for 30 to 45 min and placed in a 40°F cooler overnight. The chilled product is ready for slicing after removing the casing.

Turkey Rolls

Turkey rolls are made from breast, thigh, or mixed breast and thigh meat, and are packed in moistureproof fibrous casings. They are made for institutional use or for the retail trade.



	'A'	'B'	'C'	'D'	'E'	CASING SIZE
DET X2	1 1/16	3/8	3½ R	2¾	3½	#3
DET X3	1¼	¾	3" R	2½	3½	#4
DET X4	1 9/16	¾	3½ R	3"	3½	#6
DET X5	1⅞	13/16	3⅝ R	3⅜	3¾	#8
DET X6	⅞"	⅜"	3½" R	2½"	3½"	#2 (20)

FIG. 7-8. Turkey roll stuffing shell. Courtesy of Union Carbide, Chicago, Illinois.

Types of Turkey Rolls. The 9-lb mixed roll is made for the institutional trade. No. 8 or No. 80 × 27-in. long moistureproof casings are used. They contain 60–70% white meat and 30–40% thigh meat. Each roll contains a layer of white and dark meat. The ingredients are preweighed and gelatin is used as a binder. Spices are added to taste. Since the juices are taken up by the gelatin during cooking, the finished weight should be identical with the weight of the ingredients. The moistureproof casings prevent losses or gains in weight.

All-white-meat institutional-type rolls are also made to weigh 9 lb. Except for the fact they are made only from breast meat, they are handled the same as 9-lb mixed rolls.

Improved 9-lb Turkey Roll. Formulations are the same as for the two types just described, except they are made more solid by draining some of the cook-out juice. This is done by chilling the roll to 120°F or less. The excess juice is drained off by making a slit about 1 in. long parallel to the long axis of the roll and just inside the second clip. The casing is not cut off at the clip, but the drained roll is repressure-packed. A single uncushioned clip is used to make the final closure. The amount of juice drained off is from 10 to 14 oz for the 3- to 4-lb roll or 24 to 36 oz for the 9-lb roll. This gives a shrinkage of 20–25% during processing.

Consumer rolls are prepared from mixed or all white meat and should be of the improved type in which the cook-out juice is partially or completely removed. A No. 6 × 26-in. long moistureproof casing is commonly used.

Ingredients. Breast and thigh meat are used alone or in combination to make a mixed roll. Either fresh or frozen turkeys weighing 20–30 lb are the basic starting material. The skin may be removed intact before boning and scraped free of adhering fat, or it may be left intact on the breasts and thighs during boning. The breasts and thighs should be boned out with as little tearing or cutting as possible, so as to maintain the integrity of the muscles.

The type of seasoning is optional and a number of kinds are available on the market. Salt should be added to a level of 1½ to 2 lb per 100 lb meat. Monosodium glutamate may be added to a level of 0.5% by weight. Gelatin is added in the amount of 3 to 4 oz for 9-lb rolls and 1½ to 2 oz for 3- to 4-lb rolls. Addition of sodium phosphate is permitted, but the maximum level allowed is 0.5%. It may be injected by stitch pumping, in which case a solution of 6% should be used. The pumping level is limited to 10% or less by weight.

The following brine is recommended, where a cover brine is used:

Brine

Ingredients	*lb*	*gal*
Water		100
Salt	100	
Phosphate	50	

If the meat is to be treated with the phosphate-brine before making the rolls, this can be done using the same formula. The meat should remain in the phosphate-brine not less than 6 hr and not over 18 hr.

Preparation. A half-shell horn attached to a press is used to assemble the roll (Fig. 7.8). In assembling the roll, two pieces of breast meat are placed at the bottom of the shell horn. Seasoning and dry powdered gelatin are sprinkled over the surface of the white meat. Then dark meat is placed on top of the white meat. A pre-tied and pre-soaked casing of suitable size is then slipped over the horn. The meat is then forced into the casing, either by hand or with the press. The assembled roll is then pressure-packed and clipped.

If the skin is left attached to the meat, the meat is placed so the skin will be on the outside of the roll. If the skin is removed, it is used to line the casing before adding the meat.

The first tie may be applied to the casing either dry or after soaking. The casing should be folded back about ½ in. and the first clip applied to the doubled portion. This furnishes a shoulder to prevent the clip from slipping off during cooking. The second clip is then applied.

Cooking. Rolls are processed by immersing in hot water (175°–180°F) until the internal temperature reaches a minimum of 160°F, which is required under United States government regulations. During cooking, rolls should be held completely under water.

Institutional-type rolls are chilled in ice water to 35° to 45°F (internal temperature) and transferred to a blast freezer. Blast freezer temperatures of −45°F have been used. They should then be held at 0 to −10°F, the latter temperature being preferred.

Rolls cooked in water can be cooled to an internal temperature of 100°F by showering with cold water or placing in slush ice. They may then be frozen or stored at 32 to 36°F. Dry-processed rolls can be partially cooled at room temperature and then placed in a 32 to 36°F cooler. If the casing is not moistureproof, an additional overwrap is needed to prevent moisture loss.

Oven-Roasted Boneless Turkey Breasts

Raw Materials and Preparation. Raw turkey breasts with or without first joint wing meat and skin are used. A suggested formula for the pickle follows.

Pickle Formula

Ingredients	*lb*	*oz*	*gal*
Water			100
Salt	125		
Phosphate	50		
Dextrose	50		
Monosodium glutamate	1	4	

Trimming and Cutting. Whole turkey breasts are first boned, and the tendons, blood vessels, and excess fat are removed. The meat and skin should be trimmed so as to leave the product as nearly intact as possible. The meat and skin up to the first joint of the wing can be left attached to the breast, if desired.

Processing. The boneless, trimmed breasts are either pumped or submerged in the curing pickle. They should be held in the pickle for 12 hr.

Stuffing. One whole breast (skin on) and one half breast (skin removed) are used. The half breast is placed under the whole breast and they are stuffed into a plastic bag of suitable size. The bag is closed with conventional closing equipment.

Cooking. The product is oven-roasted at a temperature of 300°F to an internal temperature of at least 160°F. It is then partially cooled to approximately 120°F. The cooking bag is removed and the product repacked in another plastic bag. A clear gelatin solution or part of the cook-out juices can be added back to the bagged produce to improve its appearance. The bag is evacuated under vacuum, clipped, and shrunk in the conventional manner.

Cooking yields are generally about 75%. Cooking times will vary widely according to the weights, cooking method, and temperature.

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Least-Cost Formulation and Preblending of Sausage

Two relatively recent developments of great importance to the sausage industry are preblending and the application of computerized linear programming to least-cost formulation. These two developments have grown out of demands for more accurate control of costs, uniformity in composition, and maintenance of quality. Many processors, both large and small, are using one or both of these procedures in their manufacturing operations.

Although both preblending and computerized least-cost formulation are relatively new concepts, they did not develop simultaneously and are not interdependent. Thus, a processor may elect to use preblending, or computerized least-cost formulation, or even both procedures in his operation. The choice of procedure and the degree of implementation is a decision that each operator must make in view of his own capabilities and problems.

Both preblending and computerized least-cost formulation will be discussed. Although preblending will be considered first, this does not imply that it is the more important of the two. Preblending makes possible analysis prior to final formulation. It permits adjustment of formulas to meet specifications and required standards, whether they are based solely on cost, on quality, or on a combination of the two. On the other hand, selection of raw ingredients and their approximate proportions must be determined even earlier in the operation. Therefore, computerized linear programming to obtain least-cost formulas may be used before preblending.

Neither computerized least-cost formulations nor preblending are panaceas for the sausage industry, but must be applied with judgment and use of the best information possible to achieve maximum advantage.

PREBLENDING

Preblending first achieved prominence in the mid-1960s. Preblending consists of the grinding and mixing of separate meat ingredients with part or all of the cure (salt and nitrite and/or nitrate) in proportion to the amount of meat. This permits sampling and chemical analysis before the final blending or mixing of all ingredients. Some operators also add the seasoning at the same time as the cure. Other processors who make a variety of products prefer to add only the cure and then vary the seasoning to provide several different products.

Preblending has the following advantages: (1) it permits control of composition by adjusting the final blend to a known fat content; (2) addition of the cure stabilizes the meat and helps to control meat spoilage; (3) it can be used on hot boned meat, where addition of the cure results in the maximum amount of salt-extractable protein and improves emulsification; (4) preblending with the cure allows the meat to be cured while the emulsifiers and other equipment are used for other products, or even while the meat is enroute from one processing operation to another; and (5) it retards oxidation of the raw materials since the curing begins earlier.

Preblending and Control of Composition

One of the major advantages of preblending is the close control of composition made possible by analysis of the meat mixture. Immediately after the individual meat items are preblended, a sample is removed for chemical analysis. This sample is usually analyzed for fat and moisture content by one of the rapid methods discussed in Chapter 16. In some instances, although not commonly, the meat samples are also analyzed for protein content. While the analysis is being carried out, the meat is also curing through the action of the salt, nitrite and/or nitrate.

Once the composition of the samples from different preblends is known, it is possible to determine the exact combination of each ingredient to give the desired composition. Since the fat content is the most variable and since both moisture and protein are inversely related, in practice, fat is most often the only component considered. Thus, the fat content can be balanced to the desired level by adding the necessary amount of the different meat components. If the fat content is well below the desired level, a known amount of a product containing a greater amount of fat can be added to obtain the desired fat composition, or vice versa.

For example, if two preblended meat blocks have fat contents of 20% and 40%, mixing them together in the proportion of 1 : 1 will result in 30% fat content. However, the calculation is not quite this simple, as one must also consider cooking losses to obtain the final fat content. Furthermore, the processor usually adds a safety factor in order to comply with regulations. Federal meat inspection regulations specify a maximum of 30% fat for frankfurters, so that one must determine both shrinkage and cooking losses before calculating the final formulation.

Calculation of the proportion of each meat block needed to give the desired composition can also be determined by using the computer. Since some four or five different types of meat may be used in a single formulation, the advantages in using a computer to calculate the best combination of ingredients can easily be seen. Although the major decisions as to the kind of meat to be used must be determined before procurement, the computer still is a major timesaver in producing a final formula. However, one must still bear in mind that certain restrictions on the level of various ingredients must be imposed if quality is to be maintained.

Control of Meat Spoilage by Preblending

Almost, if not just, as important as the control of composition made possible by preblending are the advantages gained by cure stabilization of the preblended mixture, and thus prevention or retardation of spoilage. Once the prebatched meat begins to cure, it becomes more stable and its storage life is greatly extended. Thus, preblending changes relatively unstable fresh meat to a more stable product, in which the storage life is lengthened from a few hours or days in the fresh state to a matter of a week or so after curing. Nevertheless, it is generally desirable to limit the time before final blending to a few hours, or a day or two at most, because of inventory reduction, space requirements, and ultimate storage life. Following curing, there is a gradual decline in shelf-life as a result of microbial growth. Thus, there is an added advantage of getting the product into distribution channels while storage life is at a maximum.

Preblending of Hot Boned Meat

There are distinct advantages in curing hot boned meat. Pre-rigor meat has a greater emulsifying capacity, because the salt-soluble protein is easier to extract before the actin and myosin combine to form actomyosin, which occurs during development of rigor mortis. Although there are good reasons for using hot boned meat in all processed products, the advantages are maximal in emulsion-type products where the greater emulsifying capacity can be utilized.

Processors who also do their own slaughtering may find it advantagous to bone at once and immediately add the cure. Using hot boned bull meat in sausage emulsions has the same advantages already mentioned—the increased extraction of the salt-soluble proteins, resulting in an increase in emulsifying capacity.

The advantages of curing hot boned meat apply not only to intact cuts and emulsion-type sausages, but also to the preparation of hot boned fresh pork sausage. This product has been widely accepted, not only because of its good color, stability, and flavor, but also because of reduced inventory due to rapid turnover. When producing hot boned fresh pork sausage, some small processors have found it advantageous to use the same crew first for slaughtering and then for cutting and further processing immediately afterward. In some of these operations, the entire hog carcass is used to produce whole hog fresh pork sausage.

Preblending and Efficient Use of Equipment

Some large processors have found it feasible to preblend their meat in the boning room and to cure it while in transit to other stages of the processing operation. Since the meat is curing while in transit to the processing plant or room, there is more efficient use of certain pieces of equipment, such as the smokehouse, cook tank, and retort. Thus, total output through certain pieces of equipment can actually be increased during the working day.

At least one large processor has found it possible to cure meat while it is being trucked to their processing plants at different locations. As already explained, the meat is relatively stable after adding the cure. Undoubtedly, this permits more variation in operations.

Some processors offer preblended meat for sale to other processors and will also furnish a rapid analysis of fat content. There may be a trend toward specialized processing, one company furnishing raw products, another preblending and adding the cure, and still another serving as the final blender and processor. Although the above example of specialization is probably an extreme, within-company specialization is indeed a reality.

Preblending and Retardation of Oxidation

Rancidity is one of the most serious flavor problems of the meat industry. Sausages are especially vulnerable to rancidity or oxidative deterioration except for addition of the cure. As has already been explained in Chapter 3, the nitrite and possibly the nitrate have an important function in improvement of flavor. The better flavor after curing seems to be closely related to prevention of oxidative rancidity, although little concrete information is available at this time. Circumstantial evidence suggests that preblending reduces rancidity in sausages, probably as a result of inhibition of oxidation by the nitrite and/or nitrate. Thus, curing of hot boned meat may be expected to retard rancidity development and give a more desirable flavor. This does, in fact, appear to be real.

Use of Preblending in Least-Cost Formulation

As already indicated, preblending may be used separately from least-cost formulation using computerized linear programming, but they are most often used together. The general formulas are arrived at by the processor on the basis of cost. The amounts of various meat blocks required are determined, and the amount desired is purchased.

To make the manufacturing process more precise and the product of constant composition, each meat block is now preblended with part or all of the cure, and possibly with the seasoning. One or more samples are removed from each preblended meat block and analyzed for fat, and possibly for moisture content. After curing and analysis, the preblended ingredients are then blended together to give the final composition, the remaining cure and seasoning being added, if this has not already been done during preblending.

Special Considerations in Preblending

Although the discussion of preblending has stated that the meat be chopped, the fineness has not been specified. The fineness of chopping will depend on the uniformity of the raw meat block, the desired distribution of cure, and the difficulty of obtaining a representative sample for analysis. Lean meat can be chopped coarser than the fatter ingredients and still give a uniform sample with respect to fat content.

The consistency of the meat can also influence the uniformity of the chopped material. For example, rework sausages require especially fine grinding to give a product that can be quickly and easily mixed into the final blend. Tripe or other by-products also generally require especially fine chopping. In cases where the variation in composition is great and the meat items are hard to sample, emulsification of the raw product may need to be substituted for chopping. However, this practice should be used only as a last resort.

Raw materials for preblending should always be of good sound quality. Even though the meat is to be cured at once, quality should not be sacrificed. If the meat is rancid or partially spoiled before preblending, a lower-quality finished product can be expected.

The product should be kept at temperatures that inhibit bacterial growth. Cleanliness and good sanitation practices are required. Good raw materials and sound handling practices are just as essential in preblending as in normal processing. Quality of the finished product will be determined by the quality of the raw materials and by the type processing methods at all stages of the operation.

LEAST-COST FORMULATION

Least-cost formulation is not a new process; meat processors have used it for many years. There are limitations, however, to the number of meat items that can be employed if one uses simple machine or pencil computations. Because the amount of time required for calculations with as few as three or four meat ingredients is extremely long processors were inclined to use simple formulas involving only a few raw materials. Such formulations were obviously not necessarily of the least cost, but were those that the processors knew could be used with good results.

About 1958, a few ingenious operators began exploring the possible use of linear programming with high-speed computers to calculate least-cost sausage formulas. As is the case with preblending, most of the emphasis has been placed on emulsion-type sausages where large volume production is common. Many processors regarded computerized least-cost formulations as a modern marvel that would make the sausage business extremely profitable. Unfortunately, such has not been the case, because computer programming of least-cost formulations requires even more basic information and skill than traditional sausage formulation. Understanding of the scientific principles involved in emulsion chemistry and the functional properties of meat raw materials has become far more important as the number of raw materials available has increased. As a result, limitations or constraints have become necessary in order to maintain quality in the finished product. Consideration of these factors will be discussed later in this chapter.

Linear Programming—A Managerial Tool

A linear programming model is developed to solve four types of managerial problems: (1) a single-formula model can be used to determine the least-cost formula of one product, for example, frankfurters; (2) a composite-formula model can be used to determine least-cost formulas for many products, one at a time; (3) a multiformula model may be used where the availability of certain raw material is limited; and (4) a multi-formula model may be used to analyze the manufacturing operation in which there are certain production and procurement restrictions.

Single-Formula Model. The single-formula model is designed to determine the least-cost formula for available ingredients that will meet predetermined product specifications. It is the simplest method and provides a starting point for understanding programmed analysis of meat products. Three types of information are needed: (1) a list of available ingredients with the cost of each, (2) the composition of each ingredient, and (3) formula specifications for the product.

Composite-Formula Model. The composite-formula model greatly increases computational efficiency. One to several composite models are used to generate formulas for the entire line of products. Each composite model represents a group of products that contain essentially the same ingredients and formula specifications. Thus, one composite model may be used to generate least-cost formulas for several products, for example, to give two frankfurter formulas and one bologna formula. This model can then be used to obtain the least-cost formula for an all-beef frankfurter, for an all-meat frankfurter, and for bologna.

Multiformula Models. Multiformula models can be used whenever there are limitations in supplies of ingredients, in production capacity, or in any other component of the processing operation. In such situations, it is necessary to allocate the limited resources among the alternative products. Under these conditions, multiformula models can produce competitive least-cost formulas for several products.

The multiformula model can also be used as a management guide for decisions relative to product mix and pricing strategy, as well as to predict future profits. Thus, it can serve as a guide in formulation, raw material procurement, plant and labor utilization, product lines, and sales promotion.

Advantages of Computerized Least-Cost Formulations

By using linear programming, the meat processor can determine the specific allocation of ingredients required for a given product at a minimum cost. The product can be manufactured subject to any restrictions on composition or ingredient availability. Obviously, linear programming for least-cost formulation is aimed at improvement of profitability.

Specifically, least-cost linear programming has the following advantages: (1) it will give the most economical combination of ingredients for a given product within the limitations placed on each ingredient in the formula; (2) it permits complicated calculations that would not otherwise be possible; (3) it makes possible a saving in time alone over the more laborious traditional calculation (pencil or machine), which can be devoted to other production problems; (4) it permits adjustment of formulas on the basis of analysis, using values obtained from preblending or other sources; (5) it maximizes the use of available ingredients; (6) it reduces inventory and waste; (7) it supplies accurate procurement information; and (8) it can be utilized for making management decisions on production, promotion, pricing, and labor utilization policies.

The principal advantage of computerized least-cost formulation is that of minimizing ingredient costs of raw materials. However, the processor must first develop limitations so as to maintain product quality. This will be discussed later in this chapter under the subject of constraints. Once these limitations or constraints have been developed, the computer will give the least-cost formula. Obviously, such information can be used in procurement of raw materials, whether through intra- or inter-plant transfer or by purchase from other suppliers.

A competent worker with a desk calculator can find the most economical blend of raw materials, if allowed adequate time for calculation. In fact, prior to the use of computers for least-cost sausage formulation, a calculator was commonly used to ascertain the best combination of ingredients. However, the operator was necessarily limited to a very few ingredients, and the operation was extremely time-consuming. To illustrate the problem of manual calculation, the following example is shown.

First, assume that one has the following information on cost and composition of bull meat, cow meat, pork trimmings, and pork fat:

Ingredients	*Cost/lb ($)*	*Fat (%)*	*Protein (%)*	*Moisture (%)*	*Ash (%)*
Bull meat	0.47	8	20	71	1
Cow meat	0.45	15	18	66	1
Pork trimmings	0.30	50	10	39	1
Fat pork	0.11	70	5	24	1

Then, assuming that restrictions on composition amount to a minimum fat content of 24%, a maximum of 28% fat, and a minimum of 14% protein, one can calculate the various combinations of ingredients and their cost. The difficulties are obvious in calculating costs where the number of ingredients is limited to only four, and where the only restrictions are for fat and protein content. Even with this simple formula, the time and effort involved in arriving at a least-cost formula are tremendous. However, computer linear programming revealed that the least-cost formula and its composition within the restrictions imposed are as follows:

Ingredients	*Weight (lb)*	*Fat (lb)*	*Protein (lb)*	*Cost ($)*
Cow meat	76.4	11.46	13.75	34.38
Fat pork	23.6	16.52	1.18	2.60
	100.0	27.98	14.93	36.98

The above blend complies with the restrictions on fat and protein and gives the lowest product cost. The problem of selecting the least-cost formulation from the 25–45 ingredients available to the processor, together with the 10–15 restrictions on the blend of a single product, cannot in practice be solved without using computer linear programming.

The computer may also be utilized to adjust final blends on the basis of analysis. Information on composition obtained by analysis of preblended materials or other compositional data allows the processor to adjust the final composition carefully to comply with product specifications such as the meat inspection regulations. This results in closer tolerances with less product "give-away" in terms of protein, which is usually the most expensive component in the blend. Similarly, one can also come closer to maximum levels of fat in the final product, which is generally the least expensive of the meat components in a sausage mixture. The net effect is a uniform product in terms of composition, although not necessarily in quality.

Disadvantages of Computerized Least-Cost Formulations

Although there is little argument about the principles of computerized application for obtaining least-cost formulations, there are a number of weaknesses or disadvantages in linear programming for least-cost sausage formulas. (1) The usefulness of least-cost linear programming is limited by the accuracy of the data fed to the computer. (2) The data generated cannot be substituted for good judgment, sound scientific principles, and knowledge of the functional behavior of the raw materials. (3) Limitations must be developed for all possible combinations of raw materials. (4) Limitations on raw materials change with composition. (5) A computer requires considerable capital outlay.

Computers are not sales gimmicks installed to impress people on plant tours or even the plant labor force. They are only valuable when they are used, and used properly. The presence of a computer is not a substitute for knowledge of emulsion chemistry, the functional properties of the raw meat ingredients, or sound processing. A computer is only a tool, and the information coming out is no better than that going in. Although the computer will tell you the most economical or least-cost formulation of the ingredients, it has no knowledge of their functional properties. Thus the processor must use his knowledge in developing constraints or limitations for the various ingredients in order to maintain product quality. Only when the operator develops and utilizes such information in feeding the computer will the computer return meaningful information on cost. For these reasons operators with limited knowledge will not find a magic answer with a computer.

As already indicated, the limitations on the use of various ingredients must be fed to the computer for it to generate useful information. These limitations vary with composition and must be changed to compensate for alterations in composition. Since composition of the same meat raw materials is highly variable, especially in terms of fat and water content, the development and utilization of limitations is extremely important. Furthermore, there is marked variation in the composition of the same meat components from plant to plant, and even within the same plant. Although blending in larger quantities will help by reducing this variation, it must be considered when using computers for calculating least-cost formulations. Analysis of each meat ingredient is almost mandatory, which obviously requires a laboratory with competent personnel for obtaining the necessary analytical data.

The capital investment for a computer is considerable, even small units can cost $25,000 or more. Self-contained larger units can cost

$100,000 or more. These are only initial outlays, because up-dating and changes in computer design make older models obsolete with surprising regularity. The computer also requires maintenance by a manufacturer's representative or, alternatively, by an electronic technician on the plant maintenance staff. In addition, a computer programmer is desirable, and is absolutely essential if maximum use is to be made of a computer facility.

Although a number of specialized computer companies provide service on least-cost formulations, the formulas are usually based on an average composition. Thus, there must be great leeway of the built-in factors for safety purposes, which greatly limits the usefulness of the formulas. To further compound the problem, small companies making use of such services seldom have analytical data on composition, and most often operate without analytical laboratories for obtaining the required information. Furthermore, small operators find it difficult to compete with larger ones on cost alone, and are more likely to be on a sounder basis in producing a high-quality premium product.

Information Required for Linear Programming

In order to use linear programming effectively in a meat-processing program, an operator must perform two basic functions: (1) define the problem, and (2) collect data and formulate the model.

Defining the Problem. This consists of deciding which function is to be optimized. In least-cost formulation, the total cost of raw materials is minimized by selecting the lowest-cost ingredients after placing restrictions on their use to maintain quality. One must also ascertain what products will be produced and how large a quantity is to be blended. Since sausage production is a batch operation, the quantities in each batch are needed.

Collection of Data and Formulation of Model. Interrelationships among ingredients, restrictions on the final composition, and any other limitations must be expressed as linear equations. Ingredient costs and compositional data are perhaps the easiest information to obtain. A good analytical laboratory is necessary as a continuing part of linear programming. Knowledge of the behavior of different ingredients in a blend and their effects on the finished product is essential. Pilot-plant studies or small experimental batches should be made before going to full-scale commercial production. Constraints or limitations on raw materials must be developed on the basis of experimental data or with "educated guesses" from practical experience with sausage products. An experienced sausage man can often look at a formula and tell whether it will make an acceptable product.

Types of Constraints

The basic elements of a linear programming model are the equations or inequalities that express the restrictions on the solution. These inequalities or equations are called constraints. Constraints used in blending sausages may be due to cost limitations (objective function), ingredient limitations, composition limitations, or capacity limitations. A model linear program for least-cost sausage formulation will always contain at least one of each type of constraint. Thus it is imperative that restrictions for every relationship be incorporated into the linear program.

Cost Constraints. The objective function or cost constraint is an equation expressing the total cost of the formulation. It takes the following form, assuming there are n different ingredients that may be used in the formulation:

$$\text{Minimum cost} = C_1 \times M_1 + C_2 \times M_2 + C_3 \times M_3 \ldots + C_n \times M_n$$

where M_1 is the weight of ingredient 1, M_2 is the weight of ingredient 2 and etc., and $C_1, \ldots, C_n$ are the respective ingredient costs per pound. The per pound costs ($C_1, \ldots, C_n$) are constant coefficients supplied as input data for the model. The ingredient weight ($M_1, \ldots, M_n$) is the unknown to be computed. Since price and limitations are considered in the model, the least-cost formula will probably not contain all possible ingredients. The linear program then computes the optimal formulation and gives the weight for each ingredient.

To illustrate this principle assume there are five possible ingredients ($n = 5$) with following costs:

C_1 = \$0.20/lb	C_3 = \$0.22/lb	C_5 = \$0.40/lb
C_2 = \$0.44/lb	C_4 = \$0.80/lb	

Then assume that the computer returns the following optimal formula:

M_1 = 10 lb	M_3 = 0 lb	M_5 = 0 lb
M_2 = 88 lb	M_4 = 2 lb	

The total cost is then calculated by substituting the above values in the equation:

$$(0.20)\,(10) + (0.44)\,(88) + (0.22)\,(0) + (0.80)\,(2) + (0.40)\,(0) = \$42.32$$

Thus, a cost of \$42.32 would be the lowest possible cost for a formula satisfying the constraints in this problem.

Ingredient Constraints. These constraints are used to control the amount of an ingredient or a combination of ingredients in the blend. Such constraints can be used to limit either the minimum or maximum, to give a fixed level or a specific range (inequalities) for the ingredient. The limitations imposed may be due to poor texture (rework), taste (mutton), color (pale vs. red) or poor binding qualities (shank meat). Ingredients can be constrained singly, in pairs, or in any other combination.

An example of a single constraint is the cure, seasoning, and other dry ingredients, which may amount to 5 lb and must be used regardless of the type of meats. On the other hand, a multiple equality may be used, such as a combination of beef and pork hearts. Some processors add hearts for color and, in order to take advantage of the best buy, use both names on the label. Thus they must use some of each. Assuming a total of 10 lb in any combination together, beef hearts plus pork hearts equal 10 lb. If beef hearts equal 5 lb, then pork hearts equal 5 lb, but if beef hearts equal 1 lb, then pork hearts equal 9 lb.

Inequalities can also be used to specify either an upper or lower limit for an ingredient or combination of ingredients. For example, bull meat plus cow meat plus lean beef trimmings $\geq$ 60, that is, at least 60 lb bull meat, cow meat, and lean beef trimmings must be used. In another example, pork trim (50% fat and 50% lean) plus skinned pork jowls $\geq$ 30—at least 30 lb pork trim (50/50) and/or skinned jowls must be used. On the other hand, beef cheek meat plus pork cheek meat $\leq$ 15 lb, no more than 15 lb beef cheek meat and/or pork cheek meat may be used in the formula.

Bounding inequalities specify both an upper and lower limit for an ingredient. For example, mutton is usually limited on the low end by labeling requirements and at the upper end by flavor limitations. Thus, mutton $\geq$ 5 and $\leq$ 20, indicates that at least 5 lb mutton must be used, and the maximum must be no greater than 20 lb.

Composition Constraints. Constraints for composition are used to specify the required final composition of the blend. The specifications for such constraints are in several instances based on legal requirements plus a safety factor. In other cases, they are based on limitations on ingredients necessary to maintain quality. Since meat inspection regulations specify that the maximum fat content in frankfurters must not exceed 30%, the constraint for fat may be set at 28% to provide the necessary margin for safety.

Assuming a restriction on fat content of 28% and a formula containing cow meat, pork trim (50/50), skinned jowls, and 80% lean pork trim with an analysis of 10, 50, 70, and 20% fat, respectively, these values can be used to calculate a formula meeting the fat restriction. These constraint inequalities are then used to express the restrictions:

$$0.10 \text{ (lb cow meat used)} + 0.50 \text{ (lb 50/50 pork trim used)} + 0.70 \text{ (lb jowls used)} + 0.20 \text{ (lb pork trim used)} \leq 28.$$

Next, one may assume that the optimal computerized formula contains the following amounts of each ingredient; cow meat = 38 lb, pork trim (50/50) = 15 lb, skinned jowls = 16 lb, 80% lean pork trim = 25 lb, (assume cure and seasoning = 6 lb).

These values may then be substituted in the above equation to give the following:

$$0.10\ (38) + 0.50\ (15) + 0.70\ (16) + 0.20\ (25) = 27.5,$$

which is less than the 28% restriction and therefore satisfies the fat restriction. If one finds the unrestricted lower limit is too low in fat, one could establish bounding inequalities for fat and say:

$$\text{fat} \leq 28 \text{ and fat} \geq 26.$$

In this case, fat content would be greater than 26%, but no more than 28%.

Constraints similar to the above illustration for fat content must be developed for all other composition restrictions, which may include protein content, added moisture, color, binding qualities, and other factors associated with composition.

Capacity Constraints. A capacity constraint may be incorporated into the model to limit the quantity of production to the capacity of the plant. The capacity constraint can then be expressed in the following equation

$$M_1 + M_2 + M_3 + M_4 \ldots M_n = \text{maximum capacity},$$

where $M_1, M_2, \ldots, M_n$ are the actual weights of the n possible ingredients used in the mix. If the capacity of the system is 6,500 lb, the individual components must be computed to equal 6,500 lb. There are, however, many advantages to placing the total on a 100-lb basis since fat, protein, and moisture can then be read directly in percentages. In addition, use of a 100-lb base also gives costs directly in dollars and cents per 100 lb.

The weight or percentage of each ingredient can then be multiplied by a constant factor to obtain the actual ingredient weights needed to produce the total quantity of the blend.

Developing Constraints. Some of the limitations associated with ingredients and composition have already been briefly discussed. It is not possible to discuss each limitation, since this will depend on the product, legal requirements, the ingredients, and the properties of each. In addition, the limitations on added moisture content and shrinkage during processing must be considered. Some of these will be discussed briefly from the standpoint of how they can be used as well as some of the factors or considerations in their development. The constraints pointed out are only examples and should not be taken as actual even where numbers are arbitrarily assigned. All processors must determine their own constraints based on actual experimental information and use of their own sound judgment. It is always best to try out these constraints on small batches before changing an entire operation, at least until the constraints have been shown to be correct.

Some of the better-known constraints include fat and protein content, which have already been discussed. Other compositional constraints are added moisture and shrinkage, which will be discussed together, color, binding quality, flavor, and the use of frozen meat.

Moisture and Shrinkage Constraints. One of the government restrictions on sausages specifies that the moisture content of the finished product shall not exceed 4 times the percentage of protein plus 10% of the finished weight. In actual practice, many meat ingredients have protein-to-moisture ratios less than 4 times percent protein, while a number of other meat ingredients have moisture ratios greater than 4 times percent protein. Generally speaking, lean cuts have low protein-to-moisture ratios, while fat cuts have high protein-to-moisture ratios.

In setting up a moisture constraint, it is necessary to calculate a moisture coefficient for each ingredient because each has a different protein-to-moisture ratio. The moisture coefficient is obtained simply by using the following equation:

$$\% \text{ actual moisture} - 4 \times \% \text{ actual protein content.}$$

Thus, bull meat containing 68% moisture and 19.8% protein would have a moisture coefficient of -0.112, that is, $[0.68 - 4(0.198) = -0.112]$. For beef navels with 40.2% moisture and 10.0% protein, the moisture coefficient would be $+\ 0.002$ or $[0.402 - 4(0.100) = +\ 0.002]$. If bull meat and beef navels were the only two meat ingredients used in the formula, the moisture constraint inequality would be -0.112 (lb bull meat) $+\ 0.002$ (lb beef navels) $\leqslant 10$. This shows that the maximum amount of moisture to be added is $10 + 0.112 \times$ lb bull meat (to be computed) $-\ 0.002 \times$ lb beef navels (to be computed).

Assuming the least-cost formula under these restrictions consisted of 46 lb bull meat and 38 lb beef navels, the calculation for the amount of water to be added is as follows: 0.112 (46 lb bull meat) + -0.002 (38 lb beef navels) + 10 = 15.07% added water.

The maximum amount of moisture under governmental regulations, as already stated, is 4 times the protein content + 10. The average protein content of the blend is 12.908%, which is calculated as follows:

0.198 (46 lb bull meat) + 0.100 (38 lb beef navels) = 12.908%. Substituting this in the following equation for moisture restrictions: 4 (protein content) + 10% = % water allowed, a value of 61.63% [4 (12.908) + 10% = 61.63%] is obtained. This means that 15.07% water can be added and the formula will still comply with Federal regulations, which allow 61.63% total water.

To compensate for shrinkage, one can add the amount of water lost during processing, i.e., from the time of chopping until packaging. Temperature, relative humidity, time in the smokehouse, and internal processing temperatures influence shrinkage. Although shrinkage can be adjusted by linear programming, the simplest way is to add the amount of water lost in processing. This must be obtained from actual records and then the necessary water is added. Simply stated, if 8 lb water is lost during processing, then 8 lb can be added to the formula. This amount is in addition to that added to adjust the protein-to-water ratio.

In the example above using bull meat and beef navels, the formula then is composed of 46 lb bull beef, 38 lb beef navels, and 23.07 lb water. The water allowance includes 8 lb for shrinkage and 15.07 lb to adjust the protein-to-moisture ratio to comply with Federal regulations. This practice of adjusting for shrinkage is simpler than the use of linear programming, since the amount of water lost during processing may vary within smokehouses. This being the case, the processor can readily add more or less water to a batch, depending on which house will be used for processing.

Binding Constraints. The amount of fat that can be emulsified to form a stable emulsion is a measure of the binding qualities of the meat ingredients. Since the salt-soluble proteins are the principal emulsifying agents, lean muscle with a low content of connective tissue provides the most effective binding qualities. On the other hand, fatty tissues and lean meat with a high connective tissue content are generally poor binding components and should be avoided unless allowances are made for this. Beef and pork cheek meat, tripe, tongue trimmings, partially defatted tissue, liver, beef hearts, pork snouts and lips, pork ears, and other materials high in connective tissues are poor emulsifiers, and must have limitations placed on their use.

Tables 8.1 and 8.2 give data on the binding qualities of a number of sausage ingredients, using one system of relative rankings. The system is based on scores of 1.00 to 0.00 for excellent to poor binding qualities. This is only one method of ranking various ingredients. The values presented are averages, so do not always apply to individual cases. However, they do give some idea as to the ranking of different ingredients. Since there is considerable variation in composition and binding qualities of the same meat ingredients, some processors find it desirable to develop ranking systems of their own. Table 8.3 gives a

TABLE 8.1. Characteristics of Sausage Ingredients from Pork

Ingredients, pork	Fat level (%)	Color[a]	Bind[b]	Protein (%)	Moisture/ Protein Ratio (%)	Added Water
Bacon ends	70	0.10	0.05	8.8	2.40	26.5
Backfat, untrimmed	80	0.20	0.30	4.2	3.83	11.9
Backfat, trimmings	62	0.25	0.15	8.1	3.71	13.6
Belly, trimmings	70	0.20	0.30	6.3	3.75	12.8
Blade meat	8	0.80	0.95	19.2	3.76	16.2
Cheek meat, trimmed	15	0.65	0.75	17.8	3.79	15.2
Ears	10	0.10	0.20	22.5	3.00	36.0
Ham, boneless	19	0.60	0.80	16.9	3.80	15.2
Head meat	25	0.50	0.80	16.1	3.60	11.8
Hearts	17	0.85	0.30	15.3	4.40	4.2
Jaw meat	8	0.80	0.80	20.9	3.40	24.9
Jowls, skinned	70	0.20	0.35	6.3	3.72	13.1
Lips	31	0.05	0.10	20.1	3.42	23.8
Liver	8	0.80	0.00	20.6	3.47	23.1
Neckbone, trimmings	25	0.60	0.70	15.9	3.55	19.0
Nose meat	15	0.45	0.70	17.9	3.74	16.2
Picnic, trimmings	25	0.60	0.80	15.6	3.80	14.4
Skin	32	0.05	0.20	28.3	1.40	92.6
Skirts	30	0.50	0.45	14.2	3.90	12.6
Snouts	35	0.05	010	14.6	3.45	19.9
Spleens	15	0.60	0.00	15.9	4.33	5.2
Stomachs, scalded	13	0.20	0.05	16.7	4.20	7.3
Tissue, partially defatted	35	0.15	0.20	14.0	3.63	16.8
Tongues	19	0.15	0.20	16.3	3.95	11.9
Tongue, trimmings	32	0.15	1.10	15.6	4.34	5.1
Trimmings, lean, 95%	10	0.70	0.90	18.9	3.73	16.8
Trimmings, lean, 50%	55	0.35	0.55	9.7	3.64	15.0
Trimmings, regular	60	0.30	0.35	8.4	3.77	13.1
Weasand meat	17	0.80	0.80	16.4	4.05	10.1

[a] 0.00 = white and 1.00 for bull meat
[b] 1.00 to 0.00 in order of decreasing desirability

ranking system for binding, connective tissue, and residue as used by one company.

Not only do fat and connective tissue contents alter binding qualities, but bacterial growth and freezing both have adverse effects on binding. Thus any one or all of these factors may modify the binding qualities of the meat ingredients, and should be considered in developing constraints. Furthermore, other factors may also influence binding, and if so, should be considered in developing formulations.

Color Constraints. Appearance is an important consumer requirement, color being the most important attribute. Natural meat color is due to the combined effects of the red pigments in muscle (myoglobin

TABLE 8.2. Characteristics of Sausage Ingredients from Beef, Veal Trimmings, and Boneless Mutton

Ingredients	Fat level (%)	Color[a]	Bind[b]	Protein (%)	Moisture/ Protein Ratio (%)	Added Water
Beef fat	85	0.10	0.05	3.3	3.55	11.3
Bull meat	8	1.00	1.00	20.8	3.40	24.8
Cheeks	15	0.90	0.85	18.3	3.59	19.4
Chucks, boneless	10	0.85	0.85	19.5	3.57	20.4
Clods, shoulder	10	0.95	1.00	20.0	3.50	19.9
Cow meat, domestic	12	0.95	1.00	18.8	3.65	18.4
Cow meat, imported	10	0.95	1.00	19.0	3.65	18.6
Flanks, boneless	55	0.55	0.50	9.9	3.54	16.2
Head meat	25	0.60	0.85	16.4	3.54	19.4
Hearts	21	0.90	0.30	14.9	4.30	6.0
Lips	20	0.05	0.20	15.9	4.00	11.0
Liver	9	0.80	0.00	20.7	3.40	23.6
Lungs	12	0.75	0.05	17.5	4.00	11.0
Navels, boneless	52	0.65	0.55	10.5	3.55	16.3
Shank meat	12	0.90	0.80	16.8	4.20	7.2
Spleens	12	0.95	0.20	16.9	4.20	7.2
Tissue, partially defatted	25	0.30	0.25	18.9	3.20	15.2
Trimmings, lean, 85/90%	15	0.90	0.85	18.9	3.45	22.7
Trimmings, lean, 75/85%	25	0.85	0.80	16.9	3.41	22.2
Tongues	20	0.25	0.20	15.5	4.15	8.4
Tongue trimmings	40	0.15	0.15	12.6	3.75	14.6
Tripe	11	0.05	0.10	12.8	5.90	16.2
Weasand meat	6	0.75	0.80	17.8	4.20	7.1
Other						
Veal, trimmings	10	0.70	0.80	19.4	3.62	19.3
Mutton, boneless	15	0.85	0.85	18.1	3.70	17.1

Source: Anderson and Clifton (1967).
[a] 0.00 = white and 1.00 = bull meat
[b] 1.00 to 0.00 in order of decreasing desirability

and hemoglobin) blended into the other meat components. In other words, the percentage of myoglobin and hemoglobin in combination with muscle, fat, and connective tissue determines meat color. The blending effect is more important in emulsion-type sausages, where the color is diluted by blending the components.

Tables 8.1 and 8.2 show comparative color rankings for various meat ingredients. This system is based on using bull meat as an index of 1.00 and pure white as 0.00. Values shown in Tables 8.1 and 8.2 are given relative to these standards. The contribution of each component is obtained by multiplying the weight by the factor from the table. As with binding values, the color ranks are averages and do not reflect the range within a product; neither do they make any allowance for poor color due to bacterial action or pigment degradation.

Table 8.4 shows a color constant value for four meat ingredients.

TABLE 8.3. Ranking System for Some Compositional Constraints Used in a Commercial Operation with Values for Various Products

Products	Fat (%)	Protein (%)	Moisture (%)	Binding[a]	Connective Tissue[b]	Residue[b]
Beef cheek meat, fresh	14.8	18.5	65.7	0.513	0.323	0.164
Beef cheek meat, two days	14.8	18.4	65.8	0.232	0.450	0.326
Beef cheek meat, frozen	14.8	18.5	65.7	0.413	0.413	0.264
Beef hearts	18.0	15.0	66.0	0.222	0.153	0.622
Beef lips	19.4	16.1	64.0	0.388	0.540	0.160
Beef skirt meat	14.0	14.0	66.0	0.389	0.348	0.264
Beef tripe	6.0	14.0	79.2	0.030	0.725	0.250
Cow beef, fresh	17.6	17.8	63.6	0.650	0.200	0.160
Cow beef, frozen	6.2	20.4	72.4	0.502	0.190	0.290
Mutton, boneless	15.2	19.0	64.8	0.405	0.262	0.382
Navels, beef	46.2	12.9	41.1	0.443	0.260	0.297
Picnic, trimmings	27.1	14.8	57.1	0.540	0.154	0.299
Picnics, rough boneless	23.4	15.6	60.0	0.488	0.234	0.300
Picnics, rough boneless, frozen	14.8	18.5	65.7	0.413	0.323	0.264
Pork cheeks, fresh	25.0	15.0	59.0	0.490	0.272	0.248
Pork cheeks, frozen	25.0	15.0	59.0	0.370	0.304	0.316
Pork blade meat	14.5	18.0	57.0	0.456	0.294	0.256
Pork, fat backs	78.0	3.2	18.8	0.276	0.577	0.147
Pork, ham scraps, S.P.	35.1	10.9	53.0	0.481	0.319	0.200
Pork, head meat	10.7	18.3	70.0	0.430	0.268	0.300
Pork hearts, fresh	22.5	16.5	61.0	0.273	0.119	0.608
Pork hearts, frozen	22.5	16.5	61.0	0.034	0.202	0.774
Pork jowls	60.6	7.5	30.8	0.355	0.319	0.326
Pork lean trimmings	26.0	16.0	57.0	0.582	0.181	0.236
Pork neckbone lean	34.0	14.5	51.0	0.485	0.210	0.305
Pork, regular trimmings	55.0	9.6	34.9	0.455	0.220	0.339
Pork, snouts	36.2	15.5	46.7	0.151	0.580	0.269
Pork, stomachs	9.4	17.8	72.0	0.020	0.544	0.485
Pork, partially defatted chopped	33.0	14.7	51.3	0.268	0.206	0.388
Pork, partially defatted fatty tissue	26.0	17.4	55.0	0.079	0.607	0.326

[a] Values given for binding are based on scoring system of 1.000 to 0.000 in order of decreasing binding ability.
[b] Values are from 0.000 to 1.000 in order of decreasing desirability. In other words, high values indicate a high residue and high connective tissue content.

This value was developed by chemically determining the pigment content (myoglobin plus hemoglobin) of the tissue and expressing it as a constant color value, or as milligrams pigment per 100 g protein. To apply this value to the same meat ingredient of a different chemical composition, one multiplies the constant color value by the percentage protein. This gives a value that can be used for each product. The processor then ascertains the minimum color score that is acceptable and incorporates it into the model. This constraint will then give a least-cost model using a minimum color score.

TABLE 8.4. Constant Color Values and Percentage Protein for Four Meat Ingredients

Ingredient	Constant color value[a]	Protein (%)	Color coefficient[b]
Bull meat	23.5	20.1	4.72
Cow meat	20.7	17.8	3.68
Pork trim (50/50)	3.4	9.1	0.31
Pork cheek meat	11.3	17.2	1.94

Source: Anon. (1966).
[a] mg meat pigment/100 g protein
[b] Constant color value × % protein

Using the data in Table 8.4 for constant color values and composition, one can then obtain a practical solution for color in the linear program. For example, the color coefficients are as follows: bull meat = 4.72 (23.5 × 0.201), cow meat = 3.68 (20.7 × 0.178), pork trim (50/50) = 0.31 (3.4 × 0.091), and pork cheek meat = 1.94 (11.3 × 0.172). The color constraint can then be incorporated into the linear program by multiplying the color coefficients and the weight of each respective ingredient together and adding the results. If one uses a color constraint of ⩾ 150, then one obtains the following equation

$$4.72\ (\text{weight of bull meat}) + 3.68\ (\text{weight of cow meat}) + 0.31\ (\text{weight pork trim} - 50/50) + 1.94\ (\text{weight pork cheek meat}) \geqslant 150.$$

Assuming the computer comes up with a formula of 20 lb bull meat, 40 lb cow meat, 25 lb pork trim (50/50), and 9 lb pork cheek meat, the color score would be calculated as follows

$$4.72\ (20) + 3.68\ (40) + 0.31\ (25) + 1.94\ (9) = 266.8$$

which is well above the minimum acceptance score of ⩾ 150.

The two systems of considering color scores in developing color constraints for least-cost computerized formulations should be useful in setting up guides for color constraints. Examination of the color scores in Tables 8.1 and 8.2 does indicate the importance of considering color in any linear program. Bacon ends, backfat, belly trimmings, pork ears, jowls, lips, skin, stomachs, partially defatted tissue, tongues, and tongue trimmings are all very poor in color, whereas lean meat is relatively high. Thus consideration must be given to developing a minimum acceptable color score if linear programming is to be used for least-cost formulations.

Flavor Constraints. Flavor is probably the most important single sensory property of meat. Although people have wide differences in flavor preferences, each sausage product has a characteristic flavor made to appeal to a certain segment of the population. Consequently, flavor constraints must be carefully developed for all products. Certain meat items have characteristic flavors, some of which are not detectable until they reach a certain level. For example, it is possible to use a certain proportion of mutton in frankfurters or other products. Since lean mutton may be a good buy, bounding inequalities are often utilized, where minimum and maximum levels are specified. The minimum value of mutton $\geqslant 5$ would be to meet labeling requirements, and the maximum level of mutton $\leqslant 30$ would be to limit the upper level to avoid flavor problems. Thus, the lower level is a labeling constraint and the limiting upper level a flavor constraint.

Tables 8.1 and 8.2 give some flavor ratings for various meat ingredients. As indicated earlier, these are averages and are probably based on emulsion-type sausages. Different constraints may be necessary as one alters the formula to yield different products. For example, even low levels of boar meat is very evident in frankfurters but may be utilized at moderate levels in liver sausage and braunschweiger. Some ingredients may be so bland in flavor that constraints must be made to keep a maximum amount of flavor.

Once the limitations have been determined, the constraints are used just as in binding or color. Thus one arrives at a value for each ingredient and then, by multiplying the value for each ingredient by the weight and adding the values, a total flavor score is obtained. Once a minimum acceptable score is determined, it can be used as a constraint and will be considered in linear programming.

Frozen Meat Constraints. Some processors develop special constraints for using frozen meat. Freezing decreases binding qualities and may also cause rancidity, which decreases the flavor factor. It can also cause some decrease in the color score. All these problems may be minimized by simply limiting the amount of frozen meat to be utilized in the formula. Obviously, this may require different limitations for different ingredients and for different products.

Since the constraints for frozen meat are applied in the same way as for color or binding qualities, they will not be considered further. Suffice it to say that one may need to develop different limitations depending on the temperature and length of time in freezer storage, as temperature and time of storage can have profound effects on the properties of meat ingredients.

Poultry Meat Constraints. Federal regulations permit the use of poultry meat in sausages. With development of mechanical boning devices, large quantities of boneless meat are now available. Because of its susceptibility to oxidation, differences in flavor, and emulsification properties, poultry meat must be limited in most sausages. Unless used within a few hours after mechanical boning, poultry meat is subject to oxidative deterioration; hence constraints must be developed for sausages that contain it. The exact nature of the products being made will determine the nature of the constraints.

Deboned Meat Constraints. Federal regulations have allowed the use of deboned poultry meat in sausages for a number years, whereas, deboned red meats have been recently approved although they are limited to 20% in sausage products. There is no limit on the amount of deboned poultry meat. These raw materials are quite susceptible to oxidative deterioration and have different flavor and emulsification properties than trimmings and other raw materials. They also may alter the texture of the end products so that constraints must be developed for their use in sausages.

Deboned poultry and red meats can be successfully incorporated into sausages, as long as they are used at a relatively low level and are of high quality. Levels of 5–10% cause little or no problem, but the maximum amount should be restricted to no more than 20%. Thus, constraints need to be developed for use of deboned meats in sausage or in restructured meat products. Obviously, the constraints will vary greatly between different products.

Other Constraints. A wide variety of other constraints may be needed in production of various types of sausages. The extent of constraint must be determined by research and by common sense. Some other possible areas where constraints may need to be developed include use of partially defatted tissue, addition of cereals, use of nonfat dried milk, use of soy proteins (concentrates, spun fibers, and other soy-protein extenders), and similar compositional areas.

Once an area is known to be a limiting factor in the production or quality of sausages, it can be easily incorporated into a constraint by a series of trials to determine the best levels. Once the minimum or maximum is known, the constraints are used in the same way as outlined earlier in this chapter.

Some Examples of Least-Cost Formulations

Thus far the principles involved in arriving at least-cost formulations have been considered. To further illustrate the use of least-cost formulation for several frankfurter and bologna formulas, Table 8.5 shows data from a computer printout. The formula given is for an all-meat frankfurter. The information at the top of the table indicates some possible restrictions and their use in the formula. Immediately below this information, label restrictions for beef and pork, water added, and pork hearts are given. Next the optimum formulation using the various restrictions is listed, giving the weights, ingredients (and their input numbers), cost, and analysis. The weight and cost of the meat block, the weight of added water, and of the dry ingredients is given next. The weight and cost of the emulsion and the weight loss due to processing shrinkage then gives the weight and cost of the finished product, together with the yield and total cost of the batch. The last information in the printout from the computer gives the other available ingredients (and their input numbers), which were fed to the computer for consideration in the formulation.

The data at the top of Table 8.5 show the actual values for each possible restriction and actual restrictions used in arriving at the formula. The minimum restrictions show that the protein content must be at least 9%, color at least 15 (on the scale utilized), and emulsifying power at least 32 (based on the system used). Both beef and pork were also restricted to a minimum of 30% and combined to a minimum of 70% to meet labeling requirements. Maximum restrictions were 10% for added water, 30% for total fat, and 43% for collagen protein. Actual values for the formula show that all restrictions were met by the computerized formulation.

The optimum formula shown in Table 8.5 shows that the processor wants to incorporate a minimum of 150 lb beef plates and a maximum of 60 lb pork hearts into each batch, since both beef plates and pork hearts are on his inventory. In addition, 40 lb of dry ingredients must be incorporated into each batch.

The processor must also add 107.9 lb water to the meat block in order to adjust the protein–moisture ratio and to compensate for losses during processing. In this example, the processor has decided on 8% shrinkage, which gives the finished product weight and cost for ingredients. Given the final and beginning weights, the computer also gives a printout for product yield.

For future planning, the printout (Table 8.5) from the computer also gives the other ingredients considered in the linear program for least-cost formulation. The actual value of each of these ingredients is given, together with the penalty or cost for using them. The penalty represents the difference between the cost and the actual value in the formula. For example, pork blade meat costs $59.00 per cwt but is worth only $51.65, so the penalty for using pork blade meat is $7.35 per cwt ($59.00 − $51.65 = 7.35). The processor can use these data for adjusting his inventory by buying or selling as the situation may demand. Thus, he would probably sell any ingredients with a high cost penalty and buy those with a low penalty in anticipation of his needs.

Table 8.6 gives essentially the same data as Table 8.5 except for the arrangement of the material. The formulation can be used for either frankfurters or bologna. The limitations call for a maximum of 29.5% fat and 43% collagen protein, while minimum restrictions specify 10% protein and 32 for emulsifying power. The least-cost formulation (Table 8.6) meets all these restrictions. The labeling limitations also require that beef and pork, water added, and mutton be utilized.

Calculations for yield, shrinkage during processing, and costs of per pound and per batch are made and included in the printout. Similarly, opportunity and penalty costs are given for all products available for

TABLE 8.5. Least Cost Formula for an All Meat Frankfurter Showing Printout Information from Computer

Product Specification—Emulsion Type Restriction	Units	Min.	Actual	Max.	Cost Restriction	Units	Min.	Actual	Max.
Protein	%	9.00	10.37		Total fat	%		30.00	30.00
Moisture	%		51.47	10.00	Bind	SAF		9.60	
Color	HEME	14.00	15.93		Beef	%	30.00	30.15	
Pork	%	30.00	23.81		Beef fat	%		12.06	
Pork fat	%		17.94		Coll./Prot.	%		42.85	43.00
Water added	%		21.40		Meat	%		79.36	
Pork hearts	%		11.90		Pork cheeks	%		13.49	
Seasonings	%		7.94		Beef & Pork	%	70.00	67.45	
Emuls. power	EMS	32.00	32.00		Heart Flavor	%		11.90	

Labels—Beef & Pork, Water Added, Pork Hearts

Optimum Formulation

Weight (lb)	Percentage Green	Percentage Final	No.	Ingredient	Cost	Inventory Min.	Inventory Max.	Analysis Prot.	Analysis Coll.	Analysis Fat	Analysis Moist.	Analysis Bind	Analysis Color	Optimum Cost Range Low	Optimum Cost Range High
152.0	38.00	30.15	33	Beef plates	29.00	150.0		13.1	42.0	40.0	46.7	16.3	25.2	26.17	29.28
111.3	27.83	22.08	7	Pork trimmings 50%	18.00			9.7	34.0	55.0	35.3	11.7	9.0	17.46	24.03
68.0	17.00	13.49	21	Pork head meat	37.00			16.1	69.0	25.0	58.0	7.5	15.6	30.69	38.23
60.0	15.00	11.90	19	Pork hearts	29.50		60.00	15.3	27.0	17.0	67.3	6.1	33.2		39.49
8.7	2.17	1.72	10	Boneless picnic meat	41.00			16.3	23.0	23.0	60.7	20.1	15.9	40.46	44.97

400.0 lb of Meat Block @ $27.64/cwt.

107.9	12.71	99	Water				100.0	12.32
40.0	7.94	98	Dry ingredients	10.00	40.00	40.00		

547.9 lb of Emulsion @ $20.91 per cwt.
43.9 lb Weight Loss due to 8.0% Shrinkage
504.0 lb of Finished Product @ $22.72 per cwt.
126.0% Yield. Total Cost of Batch is $114.54.

Opportunity—Penalty Costs

					Analysis					
No.	Ingredient	Cost	Value	Penalty	Prot.	Coll.	Fat	Moist.	Bind	Color
35	Beef trimmings—85/90	59.00	48.07	10.93	18.9	27.0	15.0	65.2	24.4	38.6
14	Pork blade meat	59.00	51.65	7.35	19.2	23.0	8.0	72.2	23.7	20.0
44	Beef head meat	38.50	37.28	1.22	16.4	73.0	25.0	58.1	7.8	26.4
38	Boneless beef chucks	64.50	47.49	17.01	18.4	30.0	15.0	65.7	24.0	38.1
37	Cow meat	66.50	49.31	17.19	18.8	21.0	12.0	68.6	24.5	38.9
17	Pork cheek meat—trim	46.50	43.54	2.96	17.8	72.0	15.0	67.5	8.6	28.7
32	Beef trimmings—50%	26.00	18.03	7.97	9.8	42.0	55.0	35.0	12.3	19.0
10	Boneless picnic meat	46.00	41.00	5.00	16.3	23.0	23.0	60.7	20.1	15.9
36	Bull meat	70.00	52.87	17.13	19.8	20.0	9.0	70.7	30.0	46.5

TABLE 8.6. Least Cost Formulation for Frankfurters and Bologna Showing Printout Information from Computer

Product Specification—Emulsion Type

No.	Restriction	Units	Min.	Actual	Max.
2	Protein	%	10.00	10.31	
3	Total fat	%		29.50	29.50
4	Moisture	%		50.72	
5	Bind	SAF		10.22	
17	Coll./Prot.	%		43.00	43.00
43	Emuls. Power	EMS		34.64	

Labels—Beef and Pork, Water Added, Mutton

Optimum Formulation

Weight				Inventory		Analysis			Optimum Cost Range	
lb	No.	Ingredient	Cost	Min.	Max.	Prot.	Fat	Moist.	Low	High
223.7	32	Pork snouts	18.00			9.6	56.3	32.6	1.03	22.69
180.0	60	Boneless mutton	46.50			18.1	15.0	67.0		49.34
101.6	34	Beef trimmings—75/85	43.00			16.9	25.0	57.6	41.57	48.35
78.4	32	Beef trimmings—50	36.00			9.8	55.0	35.0	30.90	37.43

16.3	7	Pork trimmings—50	33.50			9.7	55.0	35.3	31.54	34.29

600.0 lb of Meat Block @ $33.56 per cwt.

197.6	Water			
70.0	Dry ingredients	10.00	70.00	70.00

867.6 lb of Emulsion @ $24.01 per cwt.
86.8 lb Weight Loss due to 10.0% Shrinkage
780.8 lb of Finished Product @ $26.68 per cwt.
130.1% Yield. Total Cost of Batch is $208.34.

Opportunity—Penalty Costs

					Analysis		
No.	Ingredient	Cost	Value	Penalty	Prot.	Fat	Moist.
44	Beef head meat	48.75	14.74	34.01	16.4	25.0	58.1
17	Pork cheek meat-trim	52.00	17.94	34.06	17.8	15.0	67.5
14	Pork blade meat	69.00	50.41	18.59	19.2	8.0	72.2
8	Pork trimmings-80	55.50	45.12	10.38	15.8	25.0	58.8
21	Pork head meat	52.00	17.25	34.75	16.1	25.0	58.0
45	Beef heart meat	52.50	40.27	12.23	14.9	21.0	64.1
38	Boneless beef chucks	64.50	49.70	14.80	18.4	15.0	65.7
35	Beef trimmings-85/90	68.50	52.01	16.49	18.9	15.0	65.2
29	Pork stomachs—scalded	14.00			16.7	13.0	70.1
15	Skinned pork jowls	29.00	28.30	0.70	6.3	70.0	23.4
36	Bull meat	71.00	58.10	12.90	19.8	9.0	70.7

least-cost analysis. It is interesting to note that no value or penalty is given for pork stomachs, since they could not be used and maintain the constraints for quality.

These two examples of computer printouts for least-cost formulations illustrate the nature of the information given to the processor. The restrictions used are those for a specific processor, and thus may not work for other systems, but they do illustrate how constraints are used in least-cost formulations.

SUMMARY

Preblending and computerized least-cost formulation have been discussed. Both offer certain advantages and disadvantages. They can be very useful if properly applied, but if improperly utilized they can be a source of serious problems. Preblending results in a more stable product and allows a processor to determine and adjust composition to meet any predetermined standard. Least-cost formulation by computer linear programming can result in substantial savings in product cost. However, development of constraints is necessary to avoid poor quality in the finished product. Computerized formulas must be developed with good judgment and sound knowledge about the functional properties of each ingredient and how they interact.

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9

Sausages

The term sausage is derived from the Latin word "*salsus*" meaning salt, or, literally translated, refers to chopped or minced meat preserved by salting. In ancient times, the sausage mixtures were encased in animal intestines or stomachs, and consequently were more or less cylindrical in shape. This shape is also generally a characteristic of sausages, even where synthetic casings have replaced animal casings. Thus, sausages are salted, and usually seasoned, chopped meat products that are generally, but not always, cylindrical in shape.

Sausages are one of the oldest forms of processed foods, their origin being lost in antiquity. It has been reported that sausages were used by the Babylonians and the Chinese about 1500 B.C., although documented proof for this is lacking. There are, however, a number of well-documented references to the use of sausages during the eighth century B.C., the most notable of which is Homer's "Odyssey". Homer clearly describes the cooking of meat in natural casings as follows:

> As when a man beside a great fire has filled a stomach with fat and blood and turns it this way and that and is very eager to get it quickly roasted; so to and fro Odyssey tossed and pondered how to lay hands upon the shameless suitors, he being alone and they so many.

CONSUMER ACCEPTANCE

There are literally hundreds of different sausage products available to consumers today, each having a special appeal to some part of the population. Although most of these sausages originated in Europe and were first made in the United States to meet the demand of a particular ethnic group, other population groups living in the same neighborhood frequently developed a taste for these characteristic products. As the distribution system improved and people from different geographical regions intermixed as a result of more traveling, there was an interchange and popularization of certain sausage products until some of them become almost universally acceptable. Thus, frankfurters, bologna, pepperoni, and many other sausages are available throughout the country. Nevertheless, even these universally popular products frequently vary from place to place as a consequence of flavor and season-

A. M. Pearson et al., *Processed Meats*

ing preferences. A case in point is the frankfurter, which, although universally popular throughout the United States, varies from a deep red hue and a hot spicy flavor in Texas and parts of the South to a pale pink color and mild flavor in New England and parts of the Midwest.

Although most of the sausages available in the United States are of European origin, some sausage products have originated in America, such as scrapple (once commonly called Philadelphia scrapple) and Lebanon bologna. The former is reliably reported to originally have been produced at home by farmers of Chester county, Pennsylvania, and later to be manufactured commercially by Philadelphia sausage makers. Lebanon bologna was first made by farmers in Lebanon county, Pennsylvania, who relied on a natural contamination from acid-producing bacteria and long time smoking over a wood fire in a wooden smoke house to produce a smoked, tangy flavored product. As the demand for Lebanon bologna increased, small to intermediate sausage makers adapted production to a larger scale, but still retained the old wooden smokehouses with their natural microbial populations. Traditional sausages from non-European countries have also been introduced, as is the case for the Chinese sausages, *goin chong* and *bok yu chong*.

Consumers today eat sausages because of (1) convenience, (2) variety, (3) economy, and (4) nutritional value. Sausage products take little time in preparation, with some sausages being ready to serve, and others needing only to be warmed before serving. Sausages can be easily and quickly prepared, often finding favor by working women or men. The great variety of sausages make it possible to serve many different products, each having its own characteristic appeal and flavor. Sausages are frequently served as cold cuts or as hors d'oeuvres at parties and other social gatherings. Sausages are also commonly served for breakfast, lunch, dinner or snacks.

Sausages are economical since they commonly are manufactured from the cheaper cuts of meat and from by-products. In fact, early sausage products, no doubt, resulted from the attempts of primitive man to utilize for future use the less desirable parts and by-products from slaughtering. The motto of the sausage industry well might be: "Buy a pound, serve a pound". Sausages also are of good nutritional value, since most of them contain significant amounts of high quality protein and are good sources of several essential minerals, including iron and zinc, as well as several B vitamins, including folic acid and vitamins B_6 and B_{12}. The nutritional value of sausages is discussed in greater detail in Chapter 2.

CLASSIFICATION

The term sausage covers such a diversity of products that no single classification system is completely satisfactory. Some of the more common classification systems are as follows:

1. Degree of chopping
   a. Coarsely ground
   b. Emulsion or finely chopped
2. Amount of cooking
   a. Uncooked
   b. Cooked
3. Amount of smoking
   a. Unsmoked
   b. Smoked: natural smoke; smoke flavorings, isolated smoke components
4. Amount of water added
   a. No added water
   b. Water added
5. Amount of curing
   a. Uncured (fresh)
   b. Cured
6. Amount of fermentation
   a. Unfermented
   b. Fermented
7. Amount of moisture in final product
   a. Fresh: unsmoked or smoked
   b. Smoked: fresh and cured
   c. Cooked: fresh and cured-smoked and unsmoked
   d. Cured: smoked and unsmoked
   e. Meat loaves and speciality items
   f. Dried: semidry and dry

In actual production of sausages, the products frequently cut across classifications and may fall into two or more systems. Thus, discussion is often most effective on the basis of individual products, although certain principles apply on the basis of the above systems of classification.

Classification Using USDA Meat Inspection System

The USDA Meat Inspection system of classifying sausages is probably used more widely than any other, since all federally inspected sausages come under this classification scheme. The information provided under each product is only a general guide. Furthermore, details concerning regulations frequently change, so the USDA regulations should be consulted for exact information on composition and labeling requirements.

The USDA system categorizes sausages as (1) fresh sausages, (2) uncooked smoked sausages, (3) cooked smoked sausages, (4) cooked sausages, (5) dry and semidry sausages, (6) luncheon meat, loaves, and jellied products. Each of these classes will be discussed briefly relative to generally used ingredients and labeling differences. As already indicated, details on the ingredients allowed, composition requirements and additives allowed along with labeling information can be found in USDA requirements for meat inspection.

Fresh Sausages

Made of fresh, uncured meat, generally cuts of fresh pork and sometimes beef, their taste, texture, tenderness and color are directly related to the ratio of fat to lean. Trimmings from primal cuts such as pork loins, hams, and shoulders are often used. They must be kept under refrigeration and thoroughly cooked before serving. Bratwurst is in this class. If a mixture of pork and other meats in hog casings or smaller casings are used, they need not be treated for trichinae. Mixtures in casings larger than hog casings must be treated for trichinae.

Fresh Pork Sausage. This is made from fresh or frozen pork or both including mechanically deboned pork, but not including pork by-products. The finished product cannot contain over 50% of total fat. Water and/or ice can be added up to 3% of the total to facilitate chopping and mixing.

Fresh Beef Sausage. The same as fresh pork sausage except beef is substituted for pork and the finished product cannot contain over 30% fat.

Breakfast Sausage. May be made from fresh or frozen pork and/or beef and meat by-products. May also contain mechanically deboned meat as allowed under regulations. Extenders and binders are allowed up to 3½% of the finished product, which shall not contain over 50% fat. May use up to 3% of ice or added water.

Whole Hog Sausage. Prepared from fresh or frozen meat from pigs in such proportions as are present in a single animal, otherwise the same requirements apply as in the case for fresh pork sausage.

Italian Sausage Products. Uncured, unsmoked sausages contain at least 85% meat and fat with the fat content of the finished product being limited to not more than 35%. They contain salt, pepper, and either fennel or anise or a combination of the two. It may be from pork only (Italian Sausage), from pork and beef (Italian Sausage with Beef), pork and veal (Italian Sausage with Veal), with pork, beef, and veal (Italian Sausage with Beef and Veal), and with beef or veal only (Italian Beef Sausage or Veal Sausage, respectively). If the beef or veal used is kosher, the word "Kosher" may be added to the species name. May contain up to 3% added water or ice and a number of other seasoning and flavoring ingredients.

Uncooked Smoked Sausages

These products have all of the characteristics of fresh sausage except they are smoked to give the product a different flavor and color, and they must be cooked before eating.

Fresh Smoked Pork Sausage. The same as fresh pork sausage except it has been smoked.

Fresh Smoked Kielbasa. A highly seasoned sausage of Czechoslovakian origin that is prepared from coarsely ground pork with added beef or mutton and smoked but not cooked.

Cooked Sausages

Frankfurters, Bologna, Knockwurst, and Similar Products. These comminuted, semisolid sausages are prepared from one or more kinds of raw skeletal meat and/or poultry meat. They shall not contain more than 35% fat and no more than 10% added water. May be either smoked or unsmoked. Raw or cooked poultry meat shall not comprise more than 15%. Products made from all meat or all meat from a single species may be so labeled, i.e., "All Meat" and "All Beef," respectively.

These products may also be produced to contain "by-products" or "variety meats." Must contain not less than 15% of one or more kinds of raw skeletal meat with raw meat by-products or not less than 15% of one or more kinds of raw skeletal meat with raw meat by-products and raw or cooked poultry by-products. Partially defatted pork and/or beef fatty tissue may be used in an amount not exceeding 15% of the meat and poultry meat and by-products. Other regulations given above under cooked sausages apply. If the meat comes from a single species, the name used may so indicate, i.e., "All Beef with Variety Meats," etc.

Cheesefurters and similar products are products resembling frankfurters but containing sufficient cheese to give a characteristic flavor to the finished product. May contain cereal, vegetable starch, soy flour, soy protein concentrate, isolated soy protein, nonfat dry milk, calcium reduced skimmilk, etc., not to exceed 3½% in total, exclusive of the cheese. Must be appropriately labeled.

Liver Sausage and Braunschweiger (Liverwurst). These products are made from fresh and/or frozen pork and/or beef and pork livers and/or beef livers and/or veal livers. May contain fresh, frozen and cured pork, beef, veal and pork, and pork and/or beef fat. May also contain mechanically deboned meat. Liver sausage may also contain beef and pork by-products, pork skins, sheep livers, and goat livers if appropriately labeled. An option of listing the species is given. Liver must consist of not less than 30% of the fresh weight. Binders and extenders may be used in accordance with regulations. The product is cooked and ready to serve.

Dry and Semidry Sausages

These products are produced by fermentation due to either "backslopping" (natural) or addition of a lactic acid producing-culture. The production of lactic acid not only aids in preservation by lowering the pH and inhibiting the growth of undesirable microorganisms, it adds a tangy flavor. After mixing the meat ingredients with the spices, cure, and culture, the meat is held in a curing cooler until the desired acidity is achieved. Then the meat is stuffed into casings and air dried under carefully controlled drying conditions. Some products are lightly smoked during preliminary drying, but the essential step is air drying.

Semidry Sausages. Usually fully cooked in the smokehouse to aid in the drying process, they generally have a yield of 70–80% of original weight, are semisoft due to bacterial fermentation, and have more residual moisture than dry sausages. Thuringer or summer sausages are examples.

Dry Sausages. Only lightly smoked or not at all, dry sausages generally have a yield of 60–70% of original weight, are drier, firmer, and higher in price than semidry sausages. They include salamis and cervelats.

Luncheon Meat, Loaves and Jellied Products

This group of products is widely variable and includes many unspecified products with widely different standards of identity. The products differ widely in composition and processing.

Luncheon Meat. This cured cooked product is made from comminuted meat and may contain mechanically deboned meat. Water and/or ice may be added up to 3% of total ingredients.

Meat Loaf. Made in a loaf form from comminuted meat, it may contain mechanically deboned meat and added water and/or ice up to 3% of total.

Scrapple. It must contain at least 40% meat and/or meat products on the fresh weight basis and may contain mechanically deboned meat and cereal and/or soybean flour or meal.

Bockwurst. This uncured, comminuted product may be cooked or uncooked and is made of meat, milk, or water and may contain eggs and vegetables. It must contain no less than 70% meat. Normally it contains pork only, or pork and veal, or pork, veal, and beef. However, pork may be omitted and it may be labeled accordingly, i.e., "Beef Bockwurst," etc. A number of different vegetables, seasoning, and sweetening agents are permitted in bockwurst. It may also contain mechanically deboned meat as specified in the regulations.

STEPS IN PROCESSING

An important concept to recognize is that processing of sausages is a continuous sequence of events in which each step is an integral part of the whole, thus, it is not practical to consider any one step separately or to assign more importance to one step than to another. Each step in its proper sequence is important to a successful operation. Nevertheless, in studying sausage processing, it is convenient to separate the process into definite steps or categories. The operational processing of sausages begins with grinding of the meat ingredients and proceeds through packaging.

Grinding

The grinder components are illustrated in Fig. 9.1. Meat chunks of variable size and shape and with variable fat contents are ground to form uniform cylinders of fat and lean. The worm or screw feed in the barrel of the grinder conveys the meat and presses it into holes of the grinder plate. The rotating blade cuts the compressed meat and aids in filling the grinder plate holes. The size of the holes in the grinder plate determines the diameter, and the thickness of the plate determines the length of the cylindrical particles. Particles of lean and fat passed through a ⅛-in. plate which is ⅝ in. thick will give approximately 35 million small cylinders per 1,000 lb meat. Proper mixing of these particles is extremely important to obtain a uniform blend, which is a necessary requirement if the pre-mix or pre-batching technique is to be used.

Mixing

Cylinders of fat and lean obtained by grinding are tumbled in a mixer to give a uniform distribution of fat and lean particles. This can be used for coarse-ground sausages or for emulsion-type sausages by utilizing a chopper or emulsifier, and with suitable additions of required ingredients to obtain the desired texture and uniformity of composition. Components of the mixer are illustrated in Fig. 9.2. The mixer should never be overloaded, since this prevents good mixing. Filling the mixer to the top of the paddles or blades only assures proper mixing.

Chopping

A chopper is illustrated in Fig. 9.3. It is composed of a revolving metal bowl that contains the meat, while knife blades rotating on an

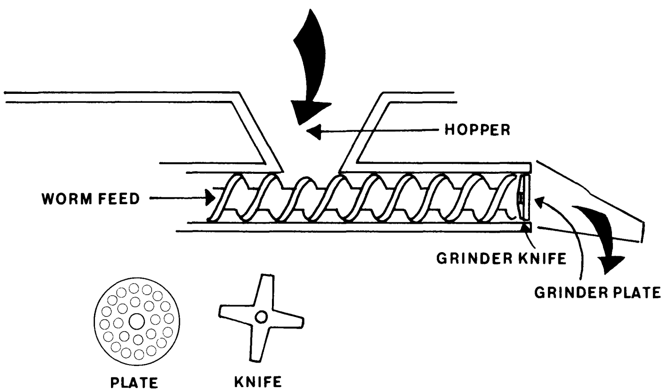

FIG. 9-1. Grinder

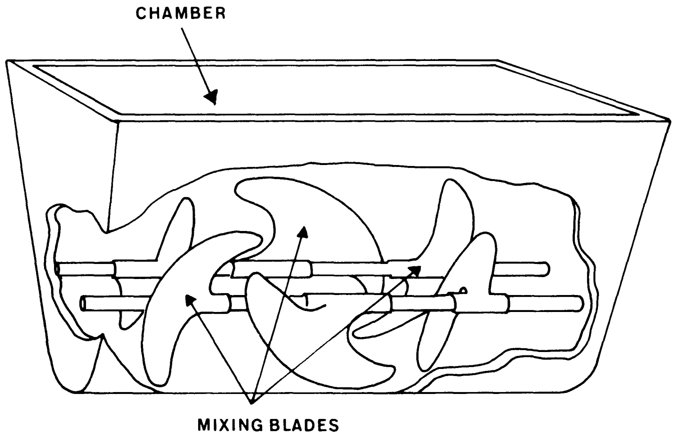

FIG. 9-2. Mixer

axle cut through the revolving meat mass. A chopper is often used as a means of batching the sausage mix, the mixed batch being transferred to an emulsifier for acquiring the desired texture. A chopper is basically a knife on an axle; speed of the knife, rpm of the bowl, and sharpness of the blades are all factors in its performance. The chopper is also called a silent cutter or a flyer. The latter is the descriptive term in New England, where chopping is sometimes called flying the meat. The temperature of the meat mass during chopping will rise 10°–20° in 10–15 min of chopping. About 25–30% of the heat used in processing is contributed by the chopper or emulsifier.

Emulsifying

An emulsifier is illustrated in Fig. 9.4. This machine combines the principles of grinding and chopping. Emulsifiers handle large volumes of meat rapidly to produce a desired texture. The emulsifier should be fed uniform mixes because it rapidly passes increments of meat mixes

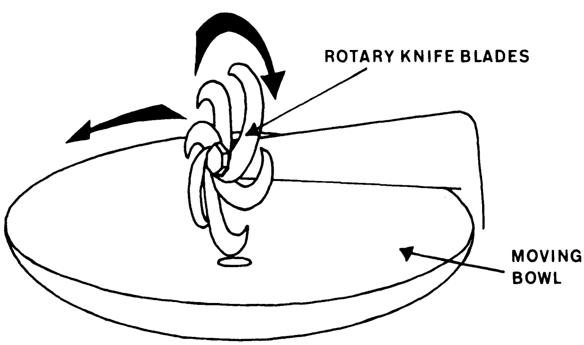

FIG. 9-3. Chopper

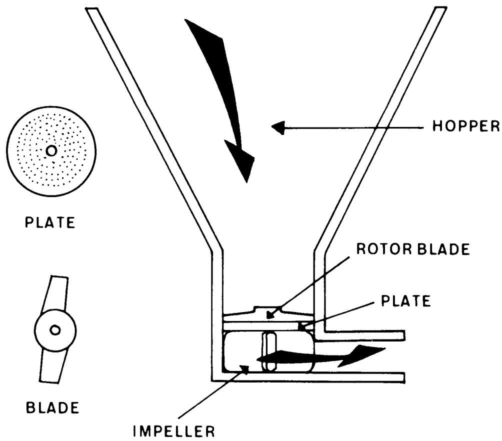

FIG. 9-4. Emulsifier

through an orifice that may hold 2 lb or less of product. In the course of a few seconds, 100 lb of meat pass through an emulsifier, with a rise in temperature of 8° to 15°F. The heat formed at the contact surfaces must be extremely high; however, accurate determinations of the amount and distribution of heat have not been made. The advantage in its use has been the speed of handling materials, the high degree of disintegration of meat tissues, and the ease of obtaining desired textures.

Stuffing

The sausage emulsion, also known in the trade as mix, sausage dough, or batter, is transferred to stuffers for extruding into casings. At this point, the size and shape of the product is determined. Three types of stuffers are used: (1) piston, (2) pump, and (3) one that combines the features of the piston and pump in a single unit.

An illustration of the components of a piston stuffer is given in Fig. 9.5. The piston-type stuffer is essentially a large barrel or cylinder that has a moving plate. The plate is usually raised by air pressure and pushes the meat mixture through a stuffing lock and finally through a tubular structure called a stuffing horn. The horn size is selected in relation to the size and type of casing to be used. Usually a horn of as large a diameter as possible is used to reduce smearing of the emulsion.

The piston-type stuffer is recommended for coarse-ground sausages and those having fat chunks, olives, pimento, and pickles, because these items may be damaged by impeller-type pumps, which usually have feedback and pop-off connectors, and are satisfactory for stuffing other emulsion-type products such as frankfurters or bologna.

The stuffer that combines features of the piston and pump usually has a volumetric delivery and is used for small sausages and for stuff-

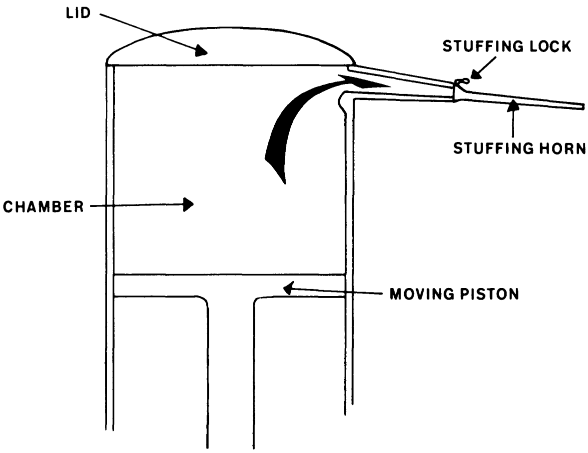

FIG. 9-5. Stuffer

ing uniform-weight rather than catch-weight products. Air pressure of 125 psi is used with many stuffers. The pumps, however, frequently work on a continuous basis, the by-pass valve handling the cycling of the emulsion when stuffing is not being carried out.

A special system for stuffing and linking skinless frankfurters has been developed, which allows automatic handling of casings. Approximately 3,000 lb or more of product per hour can be stuffed and linked with this machine.

Linking and Tying

After the emulsion is stuffed into casings, the encased mass is tied with thread or fastened with metal clips. In the case of small sausages, such as frankfurters, stuffed casings are twisted or drawn together to produce links, either by hand or with mechanical devices.

Large sausage items are tied or clipped at one end with a hanging tie and suspended from a smoke stick or hook so the entire surface is free from contact with the equipment. This permits a good flow of air around the sausages in the smokehouse and prevents touch marks and spotting due to contact with adjacently hanging products. With long bologna, 48 to 60 in. in length, the tendency is to process in uniform cellulosic casings, and place the encased bologna on a screen in a horizontal position. This horizontal processing aids in retaining a uniform cylinder of meat. If the heat capacity of the smokehouse is adequate, 25–30% more product can be placed in the smokehouse, compared to the amount held in the vertical hanging positions. This has considerable interest where slicing bologna or luncheon meats are prepared.

For frankfurters and other small sausages, hand-linking is rarely done today. Machines that stuff and link are now the accepted practice.

For 10-to-the-lb frankfurters, hand-linking of 100 lb per hour was considered excellent. Present machines will stuff and link from 600 to 3,600 lb/hr. These high-speed linkers set the production economics of the sausage industry today.

Sausage links of the 10-to-the-lb size are draped on smokesticks, eight or nine links forming a loop. A frankfurter emulsion stuffed into 25 mm casings 84 ft long gives 186 links and 18.6 lb of finished sausage. This corresponds to approximately 23 loops of eight links or 21 loops of nine links.

Smoking and Cooking

The draped smokesticks are placed on smoketrees or trolleys with 12 to 18 sticks per tree. Figure 9.6 shows a smoketree with a stick of frankfurters. The average tree holds a 42-in. stick and measures 48 × 48 × 72 in.

The filled trees are transferred to the smokehouse, and while houses of two or four trees may be used, the trend is to larger houses holding at least 10 trees. In the continuous type of smokehouse the sausages are draped on hooks, or the smokestick is conveyed on a double belt, or a moving-screen conveyor carries the product without use of sticks.

The smokehouse operation is essentially a specialized drying and cooking operation in which sausage emulsion is coagulated. The important factors relating to smokehouse performance are as follows: (1) dimension, (2) time cycle, (3) temperature range, (4) thermal re-

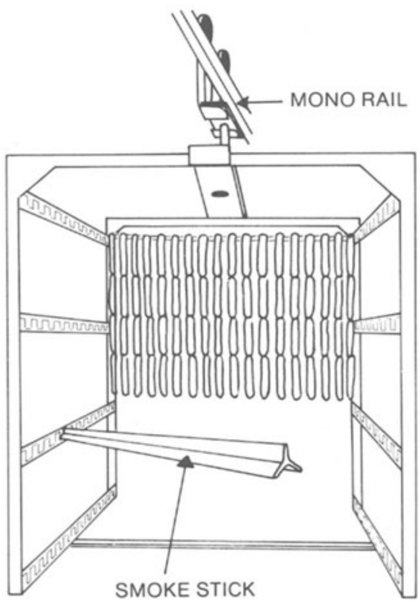

FIG. 9-6. Smoketree

quirements (Btu), (5) relative humidity, (6) air flow, (7) air flow pattern, and (8) smoke density. These factors control the environment to which the sausage will be exposed during smoking and cooking.

Encased sausage at the time of introduction into the smokehouse usually has an internal temperature of 60°–70°F. During cooking, this rises to 155°–160°F. A rise of approximately 100°F is usually needed, requiring at least 10,000 Btu for each 100 lb sausage to be cooked.

The rate at which sausages cook is influenced to a large extent by the air velocity in the smokehouse. As noted in Fig. 9.7, the greater the velocity, the faster the internal temperature of the sausage will rise. The cooking rate is much less affected by the level of humidity in the smokehouse, as indicated by Fig. 9.8 and 9.9. At high air velocities (4000 ft/min), there is practically no difference in the heating rate of frankfurters cooked in both high- and low-humidity atmospheres. However, at lower air velocities (2000 ft/min), frankfurters do cook slightly faster in a high-humidity atmosphere. The internal and surface heating rates of frankfurters are shown in Fig. 9.10.

A four-cage smokehouse, 9 ft long, 9 ft wide, and 8 ft high with a smoke-producing unit attached has a 600,000 Btu/hr rating, 40,000 Btu being supplied by the smoke generator. This smokehouse holds from 1,000 to 2,000 lb of product, and with eight to eleven changes of air per minute cooks and smokes frankfurters in 1 hr or less, and large-diameter bologna in 6 to 8 hr. The four cages, totaling 1,000 lb of sausage, require 100,000 Btu. However, the high heat-exchange poten-

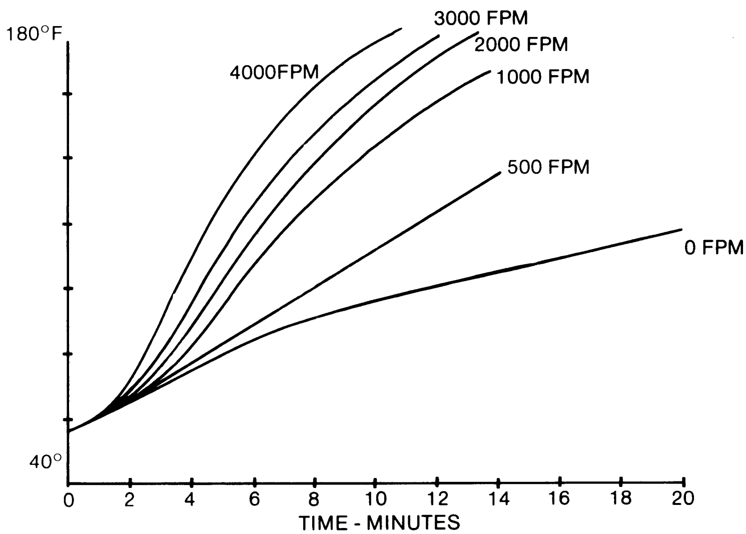

FIG. 9-7. Internal heating rates of frankfurters processed in No. 25 cellulosic casings (23 mm diameter). The frankfurters were cooked in an oven at 210°F with low relative humidity and various air velocities.

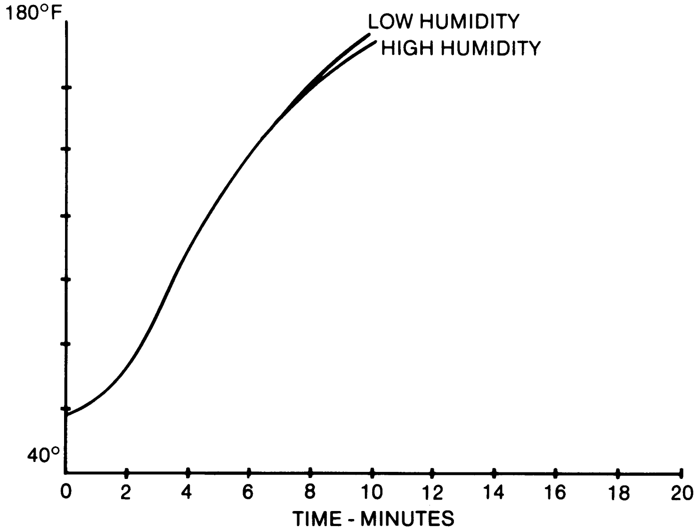

FIG. 9-8. Internal heating rate of frankfurters cooked at low and high relative humidities. The frankfurters were stuffed in No. 25 cellulosic casings (23 mm diameter) and cooked in an oven at 210°F and an air velocity of 4000 ft/min.

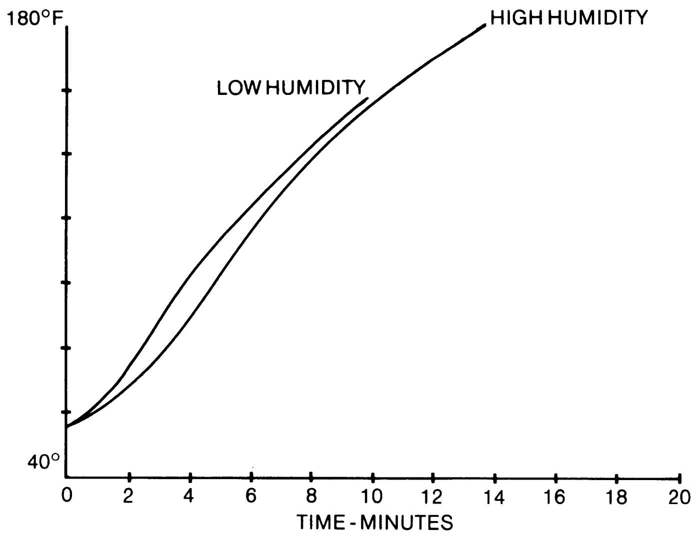

FIG. 9-9. Internal heating rate of frankfurters cooked at low and high relative humidities. The frankfurters were stuffed in No. 25 cellulosic casings (23 mm diameter) and cooked at 210°F and an air velocity of 2000 ft/min.

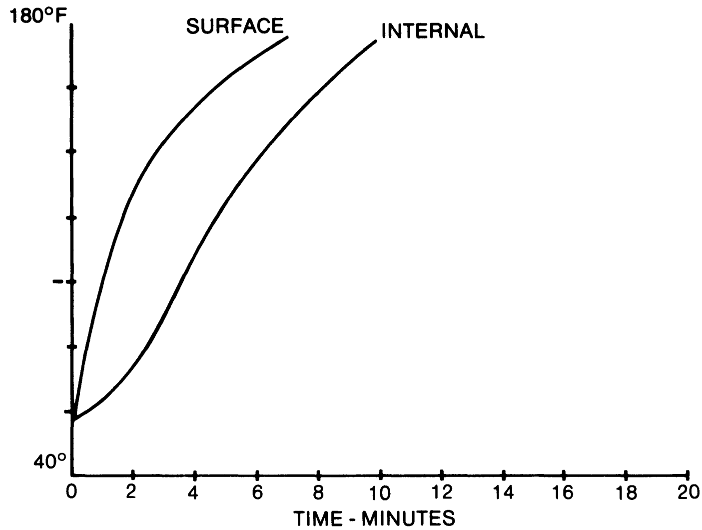

FIG. 9-10. Internal and surface heating rates of frankfurters processed in No. 25 cellulosic casings (23 mm diameter). The frankfurters were cooked in an oven at 210°F with low relative humidity and an air velocity of 4000 ft/min.

tial is important when rapid heating of the environment within the smokehouse is required. After the temperature level of the smokehouse is reached, only 15–20% of the heat is required to maintain this temperature level.

Air-flow patterns are important to production performance when the variables in size, shape, and methods of holding within a smokehouse are considered. Ham, bacon, bologna, and frankfurters, because of the size and shape differences, may require different air velocities to achieve optimum heat exchange.

Smoke-density control is necessary to obtain uniformly smoked products. Smoke density can be measured with an electric eye instrument; 30 or 40% transmission of light as recorded on the instrument has been demonstrated to provide an acceptable level of smoke on frankfurters made in continuous processing ovens.

Chilling

After smoking and cooking the product is showered with cold water and then chilled by refrigeration. On large-volume, continuous operations chilling is frequently done with a brine solution by dipping or spraying the products. A 6% salt brine is reasonably close to osmotic balance with the sausage. This brine permits lower chill temperatures and rapid cooling of the product. A 10-to-the-lb size frankfurter can be chilled to an internal temperature of 40°F in 7–8 min. The balanced brine inhibits leaching of salt from the sausage and imbibition of water by the sausage. The increased rate of chilling obtained when a brine is used is illustrated in Fig. 9.11.

Peeling and Packaging

After properly chilling the product, usually to an internal temperature of 35°–40°F, the cellulosic casings on frankfurters and slicing bologna are removed. This is known as the peeling operation. In the past, cellulosic casings were removed from frankfurters by hand, with 100–125 lb of sausage per hour considered a good rate. Modern machines remove the casings from 5,000 lb of frankfurters per hour.

Peeled frankfurters are unit-packed, usually in 1-lb units, by special packaging machinery; 6- to 10-lb bulk packages are assembled by hand. Large slicing bolognas are peeled, sliced, and packaged, 6-oz to 1-lb packages being the most popular sizes.

SOME SAUSAGE PRODUCTS

Some general information and the principles involved in production of coarse ground and emulsion-type sausages are presented.

Coarse-Ground Sausages

The manufacture of coarse-ground products such as fresh pork sausage, semi-dry, and dry sausages is described here. Formulations for these products are given in Chapter 10.

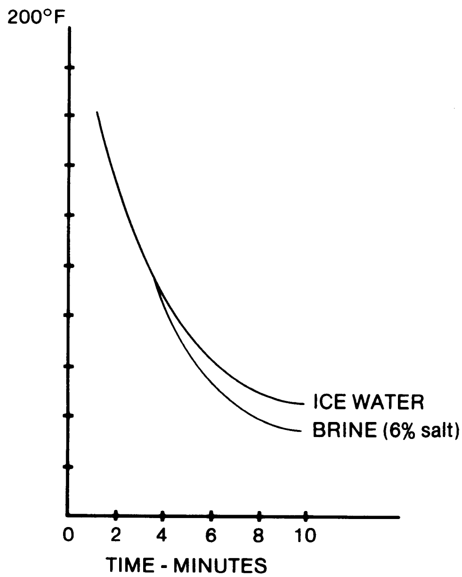

FIG. 9-11. Internal cooling rate of cooked frankfurters in ice water and brine. The frankfurters were stuffed in No. 25 cellulosic casings (23 mm diameter) and cooked to an internal of 155°F.

The various basic handling procedures and equipment used in preparing sausages have been described. This section describes the use of this information in making various sausages characterized as either coarse-ground or emulsion-type.

Fresh Pork Sausage. Pork sausage is prepared by selecting fresh, chilled pork trimmings approximately 65% lean and grinding the trimmings through a ½- to 1-in. plate. To 100 lb trimmings, add 1½ lb salt, 3 oz cane sugar, 2 oz sage, ¼ oz ginger, and 4 oz white or decorticated pepper. These are blended in a mixer and finally passed through a ¼-in. plate. The ground mixture is transferred to a piston stuffer and stuffed into sheep, hog, or collagen casings. Cloth bags, cellulosic casings, and plastic pouches are sometimes used for 1- to 6-lb units. Hog casings are stuffed and coiled in units for Country-style pork sausage.

A formation of the type described above can be prepared as a skinless-type pork sausage by stuffing into cellulosic casings of ¾-in. diameter and 40 to 50 ft in length. The casing may be shortened or lengthened as required to fit on the stuffing horn. The important point is to reduce or prevent fat smearing. The stuffed casing is linked on a Ty-linker with thread, the links draped on a smokestick and showered with 140°–150°F hot water for 5 sec to melt any fat adhering to the casing inner wall. The product is placed in a blast chill to freeze. When the internal temperature reaches 10°–15°F, the sausage is peeled by splitting the casing with a knife blade and removing the split casing. Score marks on the sausage surface are removed by holding the peeled sausage in a cooler for a few hours. This type of skinless sausage is popular in Canada where a cereal binder is included in the formula to produce a breakfast-type sausage.

A common practice today is to package pork sausage in plastic tubes using a mechanical dispenser. The tube is formed from a plastic sheet and then clipped to give a cylindrical unit pack; 3000 1-lb units or more can be prepared per hour with this type of unitized handling on a single machine.

Whole Hog Sausage. Whole hog sausage is a popular product and is made from the entire hog carcass. Sow carcasses or other heavy carcasses are often used for this product. The product can be made from hot prerigor meat, which not only saves in energy requirements but also greatly reduces meat inventories. The sausage is often made the same day that the hogs are killed. It should be rapidly chilled and can be shipped at once. This gives an attractive high quality product that has proven to be highly profitable.

Encased or packaged pork sausage is marketed either frozen or refrigerated. The lower temperatures, 0° to −10°F frozen and 28° to 36°F for chilled, permit longer shelf life and flavor retention.

Semidry Sausage. Semidry sausage is usually made from coarse ground pork or beef or a mixture of the two and is characterized by a moisture content averaging 40–45%. Fermentation is an essential step. Control is achieved by adding salt to prevent growth of undesirable bacteria, thus favoring the salt-tolerant, acid-producing bacteria, such as lactobacilli or micrococci. Dextrose (glucose) should be added at a level of 6 to 12 g per 100 lb of meat for the bacteria to use in forming lactic acid. Another essential is to have the proper bacteria present in the meat mixture, which can be achieved by either natural inoculation or by using an added specially selected culture of bacteria. The other two essentials for fermentation are time and temperature, which are required for acid production to occur. It is a good practice to measure pH in order to determine when the desired amount of acidity has developed.

Natural inoculation makes use of the bacteria present in the plant and is achieved by either (1) "chance inoculation" or (2) "back-slopping." Chance inoculation relies on the bacteria normally present in the plant. Back-slopping, on the other hand, is accomplished by adding a generous portion of meat from the previous batch of sausage along with its indigenous bacteria to each new batch.

Processors can actually culture bacteria present in their own plants and develop their own specific cultures. If the processor has a good product and is interested in developing a plant-specific culture but does not have facilities or personnel with the necessary skills for isolation and culturing the bacteria, laboratories and consultants are available for performing this service. Once a culture has been isolated and shown to produce the desired product, cultures can be stored frozen or lyophylized and held at room temperature.

Commercially available cultures can be obtained from a number of suppliers and generally are safer to use. They may be purchased either dried or frozen and contain instructions for use. Although all of these cultures utilize dextrose for growth, some of them also will hydrolyze sucrose, although more slowly. Special mutant strains of cultures have been selected by some suppliers, which do not have the capability of breaking down sucrose. These cultures can be used to produce high acidity sausages with a sweet taste since sucrose can be added and will not be broken down.

A variety of sausages are included in this category, such as summer sausage, goteberg, cervelat, thuringer, and holsteiner. They have excellent keeping qualities with little refrigeration because (1) some reduction in microbiological contaminants is achieved in the cooking process, (2) a high salt-to-moisture ratio contributes to retarding bacterial growth, and (3) a low pH (5.3 or less) provides the tangy flavor and serves a protective function. Good keeping quality is achieved with a pH of 4.8–5.0 and with a total acidity of 0.75–1.0% calculated as lactic acid.

Summer sausage is prepared by grinding pork trimmings through a ¼-in. plate and beef trimmings through a ⅛-in. plate. Place the ground meats in a mixer, add the salt, sugar, spices, cure, and starter culture, and mix for 2 to 3 min. Then regrind the mix through the ¼-in. plate. Hold the mix for 12–72 hr at 40°F. Then stuff into animal or cellulosic casings of approximately 4.5- to 5-lb capacity, using casings 3.5 in. in diameter and 22 in. long. Follow stuffing with a warm water shower for 2 min to wash the sausage surface free of any adhering particles. Smoke the encased sausage for 16 hr at 110°F. Then shower with cold water for about 15 min. Allow to stand at room temperature so the surface dries and then chill to 40°F. Semidry sausages have improved shelf life if stored refrigerated rather than at room temperature.

Dry Sausage. Semidry sausages are smoked and cooked to varying degrees, whereas dry sausage is not cooked, and only with some products is smoke applied. Fermentation, however, is common to the production of both semidry and dry sausages.

The manufacture of dry sausages is more difficult to control than that of semidry or more conventional type sausages. Overall processing time may require up to 90 days. As a result of this prolonged holding the sausage is vulnerable to chemical and microbiological degradation. However, when prepared properly, the finished sausages are usually stable and can be held with little or no refrigeration. The salt, acid, and moisture content, as well as specific types of organisms associated with the product, make for the characteristic flavor and texture of dry sausages. The raw materials and the sequence of events must be carefully controlled. Dry sausages are the "ne plus ultra" of the industry and the dry sausage maker is truly an artist.

The initial dry-sausage mixes are held under specified conditions of refrigeration to establish a medium for bacterial culture. After this, the mixture is stuffed into casings of suitable size. With animal casings the sausage is usually held in a stockinette through at least one-third to one-half the drying cycle, or until the dry casing can retain the weight of the sausage without stretching at the hanging tie. With cellulosic casings it is not necessary to use stockinettes for support. During the drying cycle the products will lose about 25–30% of their weight. The temperature, relative humidity, and air flow must be controlled so that drying proceeds properly. Air flow may vary from 15 to 20 changes per hour in the drying room. If drying is too slow the texture may be soft, the surface may discolor, and some molds or yeast may develop on the product. If drying is too fast, a surface crust develops and a brown or dark ring appears under the surface and at times marked ridges or invaginations occur at the sausage surface.

The proper ratio of fat to lean is important to give good conformation to the sausage. It is important to use well-trimmed meat and to avoid glandular tissues. Lipase in glands often splits or liquefies fat; as a result, fat drains from the sausage later in the process, producing a series of small honeycombs or pin-holes in the body of the sausages. It is important to eliminate or reduce air pockets during stuffing since the meat around these pockets will discolor. Upon continued drying, large pockets may develop in the sausage body, or a cobweb-like structure may form. Any of these conditions makes for an unattractive dry sausage. As a guide for drying conditions the Meat Inspection Service of the USDA defines the time and type of drying depending on the diameter of the sausage.

Formulations for hard salami, Genoa salami, and pepperoni are given in Chapter 10. Hard salami is cooked; Genoa is simply air-dried, while pepperoni may be either cooked or air-dried. These sausage mixes should be stuffed as cold as possible and with a minimum of pressure. This keeps the fat particles intact and reduces smearing. Fat smearing can markedly increase the incidence of rancidity and surface discoloration.

Mortadella, a dry sausage prepared in a beef bladder, illustrates very precisely the problems and limitations when sampling dry sausages. The surface or periphery is considerably different in composition from the center of the product. This condition occurs in sampling all types of sausages, but is more pronounced in dry sausages.

The mortadella analyzed was a pear-shaped product with a 2.5-in. diameter at the small end and 4.75-in. diameter at the large end, and measured 11 in. in length. This analysis, which is given in Table 9.1, also illustrates some of the mechanisms operating during production of dry sausages. Drying occurs from the outside inward, with pronounced surface drying. Some fat may render from the surface during the drying process. Also, it is obvious that the small end of the mortadella dries to a much greater degree than does the larger-diameter area under essentially the same conditions of drying.

The equipment used to manufacture dry sausages is relatively simple. Nevertheless, considerable control is needed, and some basic understanding of the fundamentals of raw material composition and of processing and handling is important for achieving this control.

TABLE 9.1. Mortadella Analysis

	Moisture (%)	Protein (%)	Fat (%)	Ash (%)
Large Diameter				
Center	49.2	18.4	24.1	6.6
Surface	33.5	27.4	30.4	5.2
Small Diameter				
Center	35.3	21.8	32.8	7.1
Surface	26.7	29.1	33.1	6.3

Emulsion-Type Products

The manufacture of emulsion-type products, such as frankfurters, bologna, and liver sausage, is described here. Formulations for these products are given in Chapter 10.

The steps in preparing emulsion sausages such as bologna and skinless frankfurters are listed in Table 9.2. These steps are common to either small products such as frankfurters or large items such as bologna.

Meat emulsions, which are not true emulsions since the two phases involved are not liquids, are made by solubilizing the meat proteins and suspending the fat particles in the protein solution. Solubilization of the myofibrillar proteins is achieved by chopping the meat with salt and water and/or ice. During chopping and mixing of the fat with the solubilized meat proteins, the fat particles become coated with the myofibrillar proteins, especially with myosin. On subsequent heating the fat particles are entrapped within the protein matrix that has formed around the fat particle. In the process of forming the solution and coating the particles in a chopper or an emulsifier, considerable heat is generated, which must be absorbed to prevent coagulation of the protein at the emulsifying stage. Ice or cold water is added to aid emulsification of the fat and to impart good flow characteristics to the emulsion, and is important to the stuffing of meat emulsion into casings. The concept of emulsification is useful in understanding some of the problems related to sausage stability. These problems are overchopping, short meat, rapid heating, and excessive heating. An analysis of these problems using the concepts of emulsion chemistry provides an understanding of the corrective measures needed and their application.

Emulsion Formation. A sausage emulsion is schematically presented in Fig. 9.12. The broken strips illustrate the lean muscle fiber with a high myosin content. The term myosin is used collectively to represent the salt-soluble, heat-coagulable proteins, and the water-soluble proteins associated with muscle. These proteins coagulate

TABLE 9.2. Steps in Preparation of Emulsion Sausages

(1) Select ingredients	(11) Chill
(2) Grind	(12) Peel or slice
(3) Mix	(13) Package
(4) Chop or emulsify	(14) Scramble
(5) Stuff	(15) Assemble
(6) Link or tie	(16) Package
(7) Hang	(17) Ship
(8) Smoke	(18) Display
(9) Cook	(19) Market
(10) Shower	

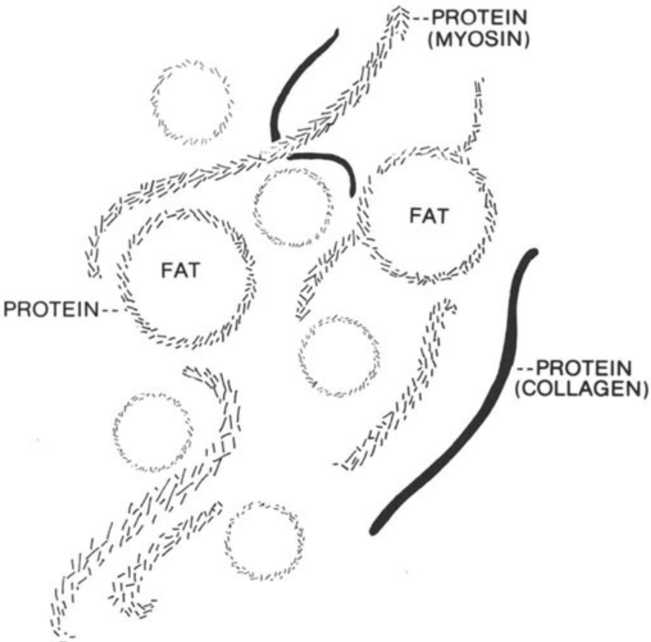

FIG. 9-12. Schematic representation of an emulsion, showing solubilized protein and fat globules coated with protein.

when heated to 135°–155°F. The solid stripes represent the connective tissues, which are rich in collagen-type proteins. Collagen fibers shrink to about one-third to their length on heating to 148°F, and with continuing heat, form gelatin. Collagen, under the conditions provided in the chopper, will imbibe considerable quantities of water. On heating, later in the process, shrinkage occurs and the moisture is squeezed from the swollen fibers. The disks are representative of the fat particles, and the broken stripes on the rim surrounding the disk or globule of fat are the salt-soluble, heat-coagulable protein of the lean muscle.

Overchopping. Figure 9.13 shows an isolated fat globule coated with the myosin-type protein. This globule, for illustration of the principle, arbitrarily measures 5 units in diameter. When this globule is chopped to give particles 1 unit in diameter, at least 125 units are formed. The volume remains the same; however, the surface of the fat increases 5-fold. As chopping is continued, the fat particles become smaller and smaller in diameter and the surface of the fat increases enormously. Eventually the fat surface becomes of such magnitude that the protein solution cannot adequately coat all of the fat particles, and uncoated or partially coated fat surfaces result. The uncoated fat renders from the mixture during heating and causes fat pocketing or

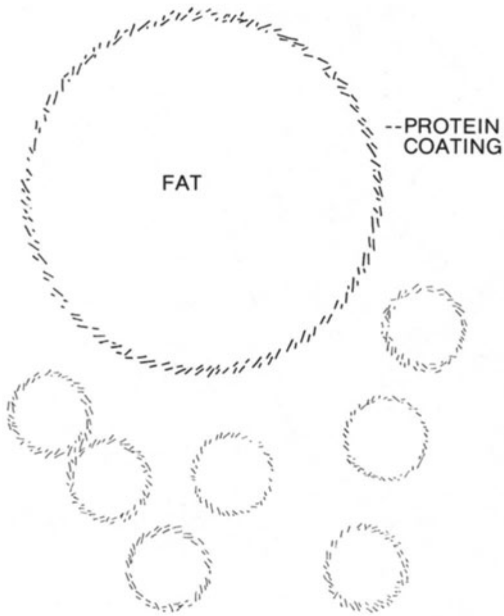

FIG. 9-13. Overchopping a sausage emulsion.

greasing out of the emulsion. An unsightly and unsatisfactory sausage results.

Short Meat. The problem is related to an imbalance of myosin to collagen in the meat components, or to a low content of lean meat in the formula. In Fig. 9.14, the fat particles covered with myosin and those covered with collagen-type protein seem identical. However, on heat-processing the collagen shrinks, converts to gelatin, and drains from the fat surface, resulting in an uncoated fat particle and a droplet of a gelatin solution. This is very serious and results in a most unsatisfactory product with a fat cap at the top of the sausage and a jelly pocket at the bottom (Fig. 9.15). When this occurs it is necessary that a thorough check be made of the formulation and the meat supply.

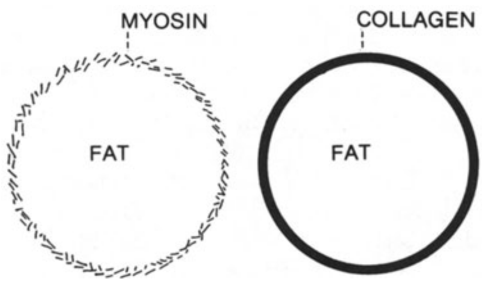

FIG. 9-14. Fat particles with myosin and collagen type proteins.

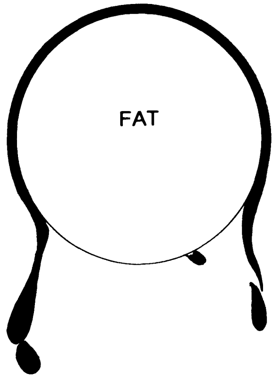

FIG. 9-15. Schematic representation of fat globule, demonstrating collagen protein converted to gelatin and draining away.

Heat Breakdown. Even when the formulation and handling techniques are satisfactory, a problem of fat separation may arise as a result of heating too rapidly or at too high a temperature. During rapid heating the protein coating sets solid and entraps the fat particle. The fat particle expands on continued heating, whereas the protein coating has a tendency to shrink. The coagulated protein sac ruptures, and entrapped fat separates or renders (see Fig. 9.16). This is encountered at times with frankfurters, and results in a small tip of fat at the smokestick mark. The surface of the frankfurter may have only a small amount of grease. This condition is not as unsightly as that resulting from overchopping or from short meat. When this type of fat separation occurs, it is necessary to review and correct the smoking and cooking schedules.

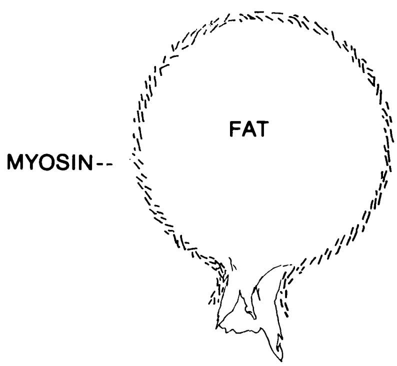

FIG. 9-16. Schematic of a fat globule which shows ruptured myosin coating and fat draining away.

OTHER MATERIALS

The types of casings, their composition and uses are covered in Chapter 11, since some of them are also used for other processed meat products. Nevertheless, the sausage industry is by far the largest user of casings. Spices, seasonings, sweetening agents, additives and extenders are also discussed in Chapter 11.

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10

Sausage Formulations

In sausage processing, each step depends on what was done before and influences each succeeding step. Careful selection of the meat for sausage formulation is important in obtaining quality products. Whole-carcass beef should contain no more than 10–12% fat, and plates, flanks, and shanks should be trimmed carefully and be used in the same ratio as in the carcass. Trimmings should be free of bone, sinews, cords and membranes. Beef trimmings may contain up to 25% trimmable fat, but should also be free of clots and bruises. Regular pork trimmings are acquired from primal cuts and trimmings removed when shaping hams, shoulders, loins, butts, and bellies. Regular trimmings should not contain more than 55% fat by analysis.

All the formulas are based on a 100 lb meat block. All additives used are based on this weight rather than on percentage. For example, the salt, sugar, spices, water, or ice are simply added and sausage yields are calculated based on the meat block rather than on the emulsion weight. The formulations will be divided in 3 sections: (1) ingredients, (2) instructions, and (3) notes.

GROUND SAUSAGES

The preparation of ground fresh sausages requires relatively few operational steps. In a manufacturing operation it is best to prepare these items first to avoid contact with cured products. All equipment must be scrupulously clean and preferably cold. If necessary, flush the equipment with ice water.

Fresh Pork Sausage

Ingredients	*lb*	*oz*
Formula 1		
Pork trimmings (65% lean)	100	
Salt	1	10
White pepper		5
Sugar		4
Sage		2
Mace		1

Fresh Pork Sausage (*Cont.*)

Formula 2		
Pork trimmings (65% lean)	85	
Fresh belly trimmings	15	
Salt	1	12
White pepper		4
Sugar		3
Sage		2
Ginger		0.5
Formula 3		
Pork trimmings (65% lean)	70	
Neck-bone trimmings	30	
Salt	1	12
White pepper		4
Sugar or dextrose		3

Instructions. Grind the chilled trimmings (38°F maximum temperature) through a ⅜-in. plate. Mix in mixer 2 to 3 min with the salt, sugar, and spices. Pass the mix through a 3⁄16-in plate. Fill stuffer and tamp the mix tightly to minimize air pockets. Use 90 to 120 lb line pressure for stuffer. Stuff into animal, cellulose, or collagen casings or suitable bulk containers.

Note. If animal casings are used, prepare casings 16 hr before use. Select 18- to 22-mm diameter casings. Wash the casings in cold water to remove salt and store in ice water. Flush just before use with 60°F water and shirr on stuffing horn. Squeeze gently on the horn to remove excess water. Hand- or machine-link.

Cellulosic or collagen casings are stuffed as removed from the package. These casings are conditioned and the moisture content is controlled by the manufacturer. They can be machine-linked. Cellulosic casing products should be dipped or sprayed for 10–15 sec with hot water (160°F) and then placed in a blast freezer until an internal temperature of 10°–15°F is reached. Remove cellulosic casings and package.

Hold product at lowest possible temperature if prolonged storage is required. For short-term storage 22°–26°F is recommended.

Canadian Pork or Breakfast Sausage

Ingredients	*lb*	*oz*
Formula 1		
Pork jowls	55	
Pork trimmings (80% lean)	45	
Ice	10	
Corn flour	3	
Salt	2	
White pepper		4
Nutmeg or mace		1

Canadian Pork or Breakfast Sausage (*Cont.*)

Thyme		0.5
Sage		0.5
Formula 2		
Jowls or regular trimmings	50	
Pork skirts	20	
Beef trimmings	15	
Back fat	15	
Ice	15	
Corn flour	4	
Dry skim milk	4	
Salt	2	
Sugar		8
White pepper		4
Ginger		1
Mace		1

Instructions. The meat ingredients are ground through a ⅜-in. plate, placed in a chopper with the spice, salt, flour, and ice, and chopped finely, usually 1 to 2 min. The chopped mixture is stuffed into animal, cellulosic, or collagen casings and handled as described in the instructions and notes for fresh pork sausage.

Chinese Sausage

Ingredients	*lb*	*oz*
Goin Chong		
Pork trimmings (80% lean)	50	
Pork back fat (diced)	30	
Pork livers	20	
Salt	2	8
Sugar	1	
Soy sauce		4
Cinnamon		1
Sodium nitrite		0.25
Bok Yu Chong		
Pork trimmings (75% lean)	75	
Back fat (diced)	25	
Salt	2	8
Sugar	1	
Soy sauce		4
Cinnamon		1
Sodium nitrite		0.25

Instructions. Grind pork trimmings through a ½-in. plate and dice the chilled back fat into ¼-in. cubes. For Goin Chong pass the livers through a ⅛-in. plate. Mix in mixer with the salt, sugar, soy sauce, spices, and curing salts. Stuff into No. 26 cellulosic casings or equivalent-sized animal casings. Link at 4-in. intervals. Heat in smokehouse at 120°F for 48 hr with no smoke added. Hold at 60°–65°F for 24–48 hr prior to packaging.

Note. These are essentially raw pork products and unless made with certified pork, the products must be heated to 137°F in a smoke-house. Usually these products shrink 30–35% during processing and storage.

Italian Pork Sausage

Ingredients	*lb*	*oz*
Formula 1 (hot)		
Pork trimmings (65% lean)	100	
Salt	1	8
White pepper		4
Fennel		4
Crushed red pepper (mild)		4
Coriander		2
Paprika		2
Formula 2 (sweet)		
Pork trimmings (65% lean)	100	
Salt	1	8
White pepper		4
Fennel		4
Paprika		2

Instructions. Grind the chilled trimmings through a ¼-in. or ⅜-in. plate. Sift the salt and spices into the coarsely ground pork while mixing, preferably with a large fork to achieve good mixing with a minimum of smearing. Stuff into hog casings, No. 30 to 36 cellulosic or collagen casings. The stuffed product may be linked or rolled into rope-type sausages.

Note. Either of these types can be prepared in bulk for pizza operations.

Skinless Smoked Links

Ingredients	*lb*	*oz*
Pork stomachs	25	
Regular pork trim	25	
Veal	25	
Pork hearts	10	
Beef trimmings	5	
Pork cheeks	5	
Bacon ends	5	
Ice	10	
Salt	1	8
Corn syrup		8
White pepper		4
Sodium nitrite		0.25

Instructions. Grind the selected chilled meat products through a ⅜-in. plate. Mix in a mixer with the ice, salt, spices, and regrind through an ⅛-in. plate. Stuff into 22-mm sheep casings or collagen casings or into No. 21 or 22 cellulosic casings. Link at 4-in. intervals. Drape on smokesticks and smoke using either hickory or hard maple wood. A representative smoke schedule follows:

Temperature (°F)	*Time*	*Smoke Instructions*
100	2 hr	Dampers closed, smoke on
120	15 min	Dampers open, smoke on
120	15 min	Dampers closed, smoke on
145	15 min	Dampers closed, smoke on
160	20 min	Until 146°F internal temperature is reached

Steam cook for 3 min at 165°F. Cold shower for 3 min, leaving some residual heat in product so no spotting occurs on transfer to a holding cooler. Cut and package animal or collagen casing products. Peel cellulosic casing and package skinless type product into 1-lb units.

Skinless Polish Sausage

Ingredients	*lb*	*oz*
Formula 1		
Beef trimmings (75% lean)	40	
Pork cheeks	35	
Regular pork trimmings	25	
Ice	10	
Salt	2	
Corn syrup	1	8
Ground black pepper		2
Marjoram		1
Sodium nitrite		0.25
Garlic		0.25
Formula 2		
Pork cheeks	40	
Beef trimmings (75% lean)	30	
Regular pork trimmings	30	
Ice	10	
Salt	2	
Corn syrup	1	8
Ground black pepper		2
Marjoram		1
Sodium nitrite		0.25
Garlic		0.25

Instructions. Grind the beef trimmings and pork cheeks through an ⅛-in. plate. Grind the pork trimmings through a ¼-in. plate.

Chop the beef trimmings and 10 lb pork cheeks with the ice, salt, spice, and cure to achieve a smooth paste. Mix the pork trimmings into the paste either in a mixer or with a few turns of the chopper. Stuff into No. 32 to 36 cellulosic casings. For short links, link to 5 to 5½ in. Long links are made 14 to 15 in., or if being prepared for a pickled sausage, 27 to 30 in. Drape linked product on smokesticks with 1½ in. between loops to permit good movement of air during the smoking process. Shower with 160°F water prior to smoking to remove grease and meat particles from the encased sausage.

Start smokehouse at 130°F for 3 hr, then increase the temperature to 150°F for ½ hr and then 170°F for ½ hr. This will result in an internal product temperature of 150°–152°F. Shower with cold water to an internal temperature of 90°F. Place in a holding cooler of 34°–38°F until the sausage is well chilled. Peel and package. The long type is usually packed two pieces to a unit package. The 27- to 30-in. lengths are cut into 1-in. cylinders and placed in a vinegar–brine solution—40 grain vinegar—with 5 lb salt added to each 100 lb vinegar. For 1 lb sausage, use ½ lb vinegar brine. Place in 1-gal wide-mouth jars. Sausage held at 40°F will keep for 2 months or more but will keep only a couple of weeks at room temperature.

Note. If a vinegar of greater strength is used, the sausage may turn brown on storage. If microbiological growth occurs in jars stored at room temperature, the packaged jars may be cooked in 150°F water for 1 hr or more depending on the size of the container; 30 min may be adequate for small jars.

The sausage may gain 5% or more in weight in the vinegar brine.

Regular Polish Sausage

Ingredients	*lb*	*oz*
Lean beef (6% fat)	25	
Beef flanks (49% fat)	10	
Pork belly trimmings (65% fat)	20	
Pork butts cured (21% fat) or picnics pumped (10% fat)	45	
Ice	12	
Salt	2	
Sugar	2	
Corn syrup	2	
Black pepper		3
Coriander		1
Ginger		0.5
Monosodium glutamate		1
Garlic		0.25
Sodium nitrite		0.125

Instructions. Chop the beef in the chopper with one-half of the ice for 4 min. Grind the other meat ingredients through the 3/16-in. plate. Place in mixer with the remaining ice, salt, sugar, corn syrup, spices, and cure. Mix for 6 min. Transfer to stuffer and stuff into 38 to 42 mm casings, either collagen or hog casings. Link into 10-in. lengths and place on smoke sticks, allowing sufficient space between sticks so the sausages do not touch each other (usually 350 lb to 400 lb per cage). The cages have three tiers with 42-in. smokesticks. Twenty sticks per cage are arranged in a 7, 7, 6 formation. Place encased product in a 40°–42°F cooler for at least 8 hr prior to smoking. Use only four cages to a six cage smokehouse to minimize crowding.

The following smokehouse schedule should be followed in order to obtain good color, texture, and flavor in the product:

Temperature (°F)	*Time*	*Smoke Instructions*
120	30–60 min	No smoke with dampers open
130	30 min	Dense smoke, dampers closed
140	90 min	Dense smoke, dampers closed
170–175	60 min	No smoke, dampers closed

Cold shower for 2 to 5 minutes, leaving some residual heat in the product so the sausage surface will dry without spotting. Transfer to a holding cooler at 38°–40°F. Package two pieces to a vacuum package for shipment.

SEMIDRY OR SUMMER SAUSAGES

Semidry sausages are coarse-ground, fermented products requiring considerable knowledge of the art. They can be prepared using starter cultures comparable to those used in the cheese industry, or they can be held under specific conditions that preferentially promote the growth of organisms that impart flavor, texture, and preservative qualities. Bacterial fermentation lowers the pH to 4.6 to 5.2. Dextrose (glucose) is added to the meat mixture as a substrate for acid production, since sucrose and other complex sugars are not readily utilized by the bacteria during fermentation.

The decline in pH as a result of fermentation not only imparts the tangy flavor and chewy texture to fermented sausages, but also aids in the drying process. As the pH drops, it approaches the isoelectric point of the major myofibrillar proteins—actin and myosin—where their ability to bind water reaches a minimum. Thus, the low pH also aids in removal of water during the drying process.

Semidry and dry sausages are not emulsion-type products, but are best classified as mixes. The meat must be reduced to the desired particle size, which requires cold temperatures during comminution and stuffing. Throughout these operations lean meats should be kept at 28°–30°F and fat meats at 27°–28°F. These low temperatures help ensure clean cutting of the meat particles and minimize smearing. Extraction of the salt-soluble proteins during comminution is not desirable; the salt functions primarily in the drying process. This requires that the meat and other ingredients be added in a definite order. Lean meats are placed in the cutter first and cut for about 1 min. Fat meats are added next and cut until the desired texture is within 1 min of being achieved. At this point, the salt and spices are added and comminution is completed.

Following preparation of the sausage mixes, they are either stuffed into casings or placed in trays or sausage trucks and stored in ripening (green) rooms. The sausages are held in the green rooms until fermentation is complete, which usually requires 2 or 3 days. The sausage pH, not the time, is the chief factor that determines the length of time needed for ripening. The green rooms are commonly maintained at temperatures of 79°–82°F and at a relative humidity of 80–90%.

Starter cultures are recommended, both because fermentation can be better controlled and since the fermentation period is greatly reduced. To determine if fermentation is complete, the pH should be measured. Whenever pH 5.0 or below is reached, the product should be ground and mixed with the cure and processed as described above.

Semidry sausages, in contrast to dry sausages, are usually placed in the smokehouse and cooked after ripening. They are generally smoked just before cooking or else during the cooking operation. Semidry sausages are often heated to an internal temperature of 140°–154°F during smoking. The finished sausages have a final moisture content of about 50%.

Thuringer

Ingredients	*lb*	*oz*
Pork trim (75% lean)	55	
Whole carcass beef	45	
Salt	2	8
Dextrose	1	
Ground black pepper		4
Starter culture		2
Whole mustard seed		2
Coriander		1
Sodium nitrite		0.25

Instructions. Grind all meats through a ¼-in. plate. Mix the ingredients in a mixer and pass the mixture through an ⅛-in. plate. Stuff into No. 2 × 16 fibrous casings. Wash the surface of the encased product with a hot shower for ½ to 2 min. Hang at room temperature for 2 hr and transfer to a smokehouse at 110°F for 12 hr. Maintain a dense smoke in the house. Finish at 120°F for 4 hr. Remove from the smokehouse and allow to stand at room temperature for 2 hr. Transfer to a holding cooler. The finished product should have a salt content of 3% and pH of 4.8 to 5.0.

Note. The pork must be certified pork trimmings, or an internal temperature of 137°F must be obtained during smoking. The use of the starter culture markedly reduces the processing time.

Cervelat

Ingredients	*lb*	*oz*
Formula 1		
Beef trimmings	70	
Regular pork trimmings	20	
Pork hearts	10	
Salt	3	
Sugar	1	
Ground black pepper		4
Sodium nitrate		2
Whole black pepper		2
Formula 2		
Beef trimmings	80	
Regular pork trimmings	20	
Salt	3	
Sugar	1	
Ground black pepper		4
Whole black pepper		2
Sodium nitrite		0.25

Instructions. Grind the beef trimmings and hearts through a ¼-in. plate. Grind the pork trimmings through a ⅜-in. plate. Mix the ground materials with the salt, sugar, ground pepper, and nitrate, withholding the whole black pepper. After mixing, regrind through an ⅛-in. plate and add the whole black pepper. Mix with a kneading action for 2 min. Transfer to an 8-in. deep pan and hold at 38°–42°F for 48–72 hr. Remix after removal from the pans and stuff into No. 2 or 2½ fibrous casings. Hang in a drying room for 24 to 48 hr at 55°F and then place in a smokehouse for 24 hr at 80°F. Slowly increase the temperature of the smokehouse to 115°F and hold for 6 hr or more until a good color develops on the sausage. Cool by holding at room temperature for several hours prior to transfer to a holding cooler.

Note. The pork must be from certified trimmings, or the internal temperature of the sausage must reach 137°F during smoking.

Lebanon Bologna

Ingredients	*lb*	*oz*
Whole carcass cow meat	100	
Salt	1	8
Sugar	1	
Mustard		8
White pepper		2
Ginger		1
Mace		1
Sodium nitrite		0.25
Sodium nitrate		2.75

Instructions. Typically, Lebanon bologna is made from whole-carcass cow meat, which is salted with 2% salt and held for 8 to 10 days at 34°–38°F for fermentation. If starter cultures are added, the fermentation period can be materially reduced. Starter cultures are recommended, because fermentation can be better controlled. To determine if fermentation is complete, the pH should be measured. Whenever pH 5.0 or below is reached, the product should be processed as described. The beef is ground through a ½-in. plate and mixed in a ribbon mixer with the salt, sugar, spices, and sodium nitrite. The mixture is then passed through an ⅛-in. plate and stuffed into No. 8 fibrous casings. The filled casings are tied and stockinetted for support. The product is transferred to a smokehouse for a 4- to 7-day cold smoke, usually 4 days in the summer months and 7 days in the late fall and winter months.

Note. Lebanon bologna is traditionally made under conditions that call for little or no refrigeration. The finished product is extremely stable even though the moisture content may be as high as 55–58%. The salt content of the finished product is usually 4.5–5.0% and the pH ranges from 4.7 to 5.0.

The sausage is processed traditionally in outdoor wooden smokehouses using a wood fire inside the house and a metal baffle plate to direct the heat. The ventilator doors at the top of the house are opened or closed at the discretion of the smokehouse operator.

Chorizos

Ingredients	*lb*	*oz*
Pork trimmings (85% lean)	35	
Regular pork trimmings	35	
Neckbone trimmings	30	
Salt	2	8
Sugar		8

Chorizos (*Cont.*)

Sweet red peppers	6
Chili powder	6
Red pepper (hot)	2
Sodium nitrite	0.25
Garlic powder	0.25

Instructions. Grind the chilled pork trimmings through a ¼-in. plate. Mix in a mixer with the salt, sugar, sodium nitrite, and spices. Stuff into animal or collagen casings of 24 to 26 mm, or into No. 27 cellulosic casings. Link at 4-in. intervals. The sausage may be packaged at this stage as a fresh chorizo. If it is to be processed further, it is dried at 54°–58°F for 10 days or lightly smoked and dried for 15 to 20 days at 55°–58°F. The product is sometimes packaged in lard somewhat comparable to sausage in oil products.

Note. The term hot in relation to spicing is difficult to define, consequently, more or less hot red pepper may be used at the discretion of the sausage producer.

DRY SAUSAGES

The manufacture of dry sausages is steeped in art. However, the art is slowly yielding to the advancement of science.

Like semidry sausages, dry sausages are fermented products. Dextrose is added to provide a substrate for the desirable bacteria, which use it to produce acid and lower the pH. Fermentation is accomplished either by the naturally occurring microbial population or by adding starter cultures of selected bacteria. The starter cultures generally contain *Lactobacillus, Leuconostoc* or *Micrococcus* organisms. *Periococcus cerevisae* has also been widely used in starter cultures for producing both dry and semidry sausages. The sausage mixtures are held in a ripening room or "green room" during the fermentation process.

After fermentation or ripening, dry sausages are moved into drying rooms held at temperatures of 50°–63°F and at a relative humidity from 65 to 85%, depending on the type of product being produced. Air movement must be carefully controlled, with about 15 to 20 air changes per hour being common in meat drying rooms. Dry sausages commonly have a moisture content of about 35% when finished.

Molds often develops in dry sausages during drying. They are easily removed by rubbing with a clean cloth soaked in edible oil. Federal meat inspection regulations also permit soaking of the casings in a 2.5% potassium sorbate solution or in a 3.5% propylparaben solution before stuffing in order to inhibit mold growth.

Genoa (Beef and Pork)

Ingredients	*lb*	*oz*
Formula 1		
Beef chucks	40	
Pork shoulder trimmings	30	
Regular pork trimmings	30	
Salt	3	8
Sugar	2	
Burgundy wine		8
White ground pepper		3
Whole white pepper		1
Sodium nitrate		0.5
Garlic powder		0.25
Formula 2		
Lean pork trimmings (85% lean)	60	
Regular pork trimmings	40	
Salt	3	8
Sugar	2	
Burgundy wine		8
White ground pepper		3
Whole white pepper		1
Sodium nitrate		0.5
Garlic powder		0.25

Instructions. Grind the lean meats through an ⅛-in. plate and the fat pork through a ¼-in. plate. Mix the salt, sugar, spices, wine, and sodium nitrate in a mixer for 5 min, or until a satisfactory mix is obtained. Hold the mix in trays 8 to 10 in. deep for 2 to 4 days at 38°–40°F. The holding period can be reduced to a few hours if starter cultures are used.

Stuff into a No. 5 × 22 fibrous casing, sewed bungs, or suitably sized collagen casings. Hold in a green room at 70°F and 60% relative humidity for 2 to 4 days, or until the sausage stiffens and a pink color develops on its surface. Store in drying rooms at 53°F and 60% relative humidity for 90 days. A minimum moisture loss of 24% in the dry room is desirable for obtaining a good product.

Note. Good color, no yeasty or rancid surface flavor, a moist texture in the center and a minimum of surface crusting are requirements for good dry sausage.

Control of the air flow in the drying room is important but difficult, since products of varying moisture are present and the air-flow pattern is not well defined. Usually, 15 to 20 air changes per hour is a good rate. The shifting of product is important for maintaining good drying. The rooms should be kept dark; low-intensity ruby lamps can be used, since intensity of lighting can be a factor in surface discoloration. Product may be bunched or spread on a stick, or the stick may be shifted from the bottom to the top of a rack, depending on the drying pattern. Low fat-content products and small-diameter products will shrink more readily than higher-fat and large-diameter products.

B. C. Salami (Hard)

Ingredients	*lb*	*oz*
Beef chucks	40	
Pork jowls, glands trimmed	40	
Regular pork trimmings	20	
Salt	3	8
Sugar	1	8
White pepper		3
Sodium nitrate		2
Garlic powder		0.25

Instructions. Grind the beef through an ⅛-in. plate and the pork through a ¼-in. plate. Mix all the ingredients in a mixer for 5 min, or until a good distribution of the fat and lean is apparent.

Store the mix in trays 8 to 10 in. deep for 2 to 4 days at 40°–45°F. Stuff into No. 5 × 22 fibrous casings, sewed bungs, or suitable-sized collagen casings. Hold stuffed product for 9 to 11 days at 40°F and 60% relative humidity.

Holding times both during fermentation and drying can be greatly reduced if starter cultures are used. Directions for their use vary for different manufacturers and should be carefully followed.

Note. If product molds in the drying room, some correction of the relative humidity is needed. The molded product should be wiped with an oiled rag to remove mold. The dry room may require a thorough cleanup.

In animal casings, the sausage is usually held in stockinettes for the first half of the drying cycle. After this period of drying, the encased sausage can be suspended from the tying string for the remainder of the drying period without stockinettes.

Pepperoni

Ingredients	*lb*	*oz*
Regular pork trimmings	45	
Beef chucks	30	
Pork hearts	15	
Pork cheeks	10	
Salt	3	8
Sugar	1	
Sweet paprika		12
Decorticated ground pepper		6
Capsaicin		4
Whole fennel seed		4
Sodium nitrite		0.25

Instructions. Grind all the meat ingredients through a ½-in. plate, and then through an ⅛-in. plate. Add the spices, salt, sugar, and nitrite and mix for 5 min, or until a good distribution of the ingredients is apparent. Stuff into 38 to 44 mm animal casings, or if for slicing product, No. 1 × 32 fibrous casings. Hold for 9–11 days at 38°F. Transfer to a green room maintained at 65°F and 69% relative humidity and hold for 48 hr.

Smoke for 60 hr at 90°F. Use a dry smoke until red color develops then adjust relative humidity to 80% and finish smoking.

Hold for 21 days in a drying room at 53°F and 69% relative humidity. Shrinkage is about 35%.

Note. The traditional Italian-style pepperoni is not smoked. Smoke-flavored pepperoni is objectionable to the Italian trade.

The pizza trade requirements are frequently met by supplying the pepperoni as a cooked product where the product is held at 120°F for several hours and finally processed in a 145° smokehouse with smoke until the internal temperature reaches 137°F.

As with other dry and semidry sausages, use of cultures will greatly reduce the time needed for fermenation. Utilization of cultures also assures better control of the fermentation process. Either commercially available cultures or cultures prepared from isolates obtained from successful sausage production may be used.

EMULSION-TYPE SAUSAGES

Emulsion products have a high degree of acceptance resulting from the texture and flavor achieved in processing. The formulations have been used by a large number of sausage companies throughout the United States. Federal inspection regulations governing the moisture–protein ratios and fat levels in emulsion type sausages have tended to promote a degree of uniformity in formulas.

All Meat Bologna

Ingredients	*lb*	*oz*
Whole-carcass beef	60	
Regular pork trimmings	40	
Ice	25	
Salt	2	12
Sugar		8
Ground white pepper		4
Coriander		1
Mace		1
Sodium erythorbate		0.85
Sodium nitrite		0.25

Instructions. Grind the beef through a 1/4-in. plate and the pork through a 3/8-in. plate. Mix in a mixer with the spices, salt, sugar, erythorbate, and nitrite. Add ice or equivalent weight of ice and water depending on the temperature of the mix. Pass through a double-plate emulsifier to acquire the desired texture. The temperature rise of the mix passing through the emulsifier is usually 8°–15°F.

If the emulsion is prepared in a conventional chopper, place the ground beef in the chopper with half the ice. Add the salt, erythorbate, and sodium nitrite and chop to a smooth paste, approximately 5 min. Add the remaining ice, spice, sugar, and pork trimmings and chop to the desired texture, usually for an additional 5 min, or until a temperature of 55°–58°F is achieved.

Transfer the finished emulsion to a stuffer and stuff into casings. It is important to use as large a horn on the stuffer as is compatible with the casings. This permits lower stuffing pressures. A line pressure on the stuffer of 70 to 110 psi is usually required. A No. 8 × 36 in. fibrous casing gives a bologna of approximately 18 lb with a 15-in. circumference.

This size product will require approximately 8 hr in the smokehouse. It is best to start at a house temperature of 130°F with the damper open. Cook for 30 min and then close the damper and raise the temperature 10°F/hr to 170°F. Continue to heat at 170°F until an internal temperature of 156°F is reached. Cold shower for 35–40 min. Hold for at least 30 min at room temperature prior to placing the sausage in a 36°–40°F holding cooler.

Note. Bologna prepared for slicing and prepackaging requires careful control of size. It is preferable to use a casing that has been specially treated for easy release from the bologna surface.

Bologna (Milk Powder)

Ingredients	*lb*	*oz*
Formula 1		
Regular pork trimmings	60	
Carcass beef	40	
Ice	25	
Dry skimmilk	4	
Salt	2	12
Sugar	1	
White pepper		2
Coriander		1
Mace		1
Sodium erythorbate		0.85
Sodium nitrite		0.25
Formula 2		
Carcass beef	50	
Fat back	25	
Regular pork trimmings	25	
Ice	25	
Dry skimmilk	4	
Salt	2	12
Sugar	1	

Bologna (Milk Powder) (*Cont.*)

White pepper		2
Coriander		1
Mace		1
Sodium erythorbate		0.85
Sodium nitrite		0.25
Formula 3		
Regular pork trimmings	40	
Beef trimmings	30	
Carcass beef	20	
Fat back	10	
Ice	25	
Dry skimmilk	4	
Salt	2	12
Sugar	1	
White pepper		2
Coriander		1
Mace		1
Sodium erythorbate		0.85
Sodium nitrite		0.25
Formula 4		
Beef trimmings	60	
Regular pork trimmings	40	
Ice	25	
Dry skimmilk	4	
Salt	2	12
Sugar	1	
White pepper		2
Coriander		1
Mace		1
Sodium erythorbate		0.85
Sodium nitrite		0.25

Instructions. Follow the same instructions as for manufacture of all meat bologna.

Bologna (Imitation)

Ingredients	*lb*	*oz*
Formula 1		
Beef weasand meat	30	
Beef trimmings	25	
Pork tongue trimmings	20	
Beef cheeks	10	
Pork stomachs	10	
Pork fat	5	
Ice	30	
Wheat flour	14	
Salt	3	
Sugar	1	
White pepper		4
Garlic powder		1
Sodium nitrite		0.25

Bologna (Imitation) (*Cont.*)

Formula 2		
Beef trimmings	20	
Beef weasand meat	20	
Pork tongue trimmings	15	
Mutton	15	
Beef cheeks	10	
Pork stomachs	10	
Pork hearts	5	
Pork fat	5	
Ice	30	
Wheat flour	14	
Salt	3	
Sugar	1	
White pepper		4
Garlic powder		1
Sodium nitrite		0.25
Formula 3		
Beef trimmings	40	
Beef lips	20	
Mutton	10	
Sweet pickle trimmings	10	
Beef weasand meat	10	
Pork hearts	5	
Pork fat	5	
Ice	30	
Wheat flour	14	
Salt	3	
Sugar	1	
White pepper		4
Garlic powder		1
Sodium nitrite		0.25
Formula 4		
Beef trimmings	25	
Beef hearts	20	
Beef tripe	20	
Back fat	20	
Pork stomachs	10	
Pork fat	5	
Ice	30	
Wheat flour	14	
Salt	3	
Sugar	1	
White pepper		4
Garlic powder		1
Sodium nitrite		0.25

Instructions. Grind beef, beef cheeks, and mutton through an ⅛-in. plate and the pork fat through a ¼-in. plate. Emulsify the other ingredients to give a smooth paste. For the remainder of the manufacturing follow instructions given for meat bologna.

Small-diameter emulsion-type sausage are the most popular sausages manufactured in the United States.

Frankfurters (Meat)

Ingredients	*lb*	*oz*
Formula 1		
Whole-carcass beef	60	
Regular pork trimmings	40	
Ice	30	
Salt	3	
Corn syrup	2	
White pepper		4
Nutmeg		1
Sodium erythorbate		0.85
Sodium nitrite		0.25
Formula 2		
Whole-carcass beef	50	
Pork jowls	50	
Ice	40	
Salt	3	
Corn syrup	2	
White pepper		4
Nutmeg		1
Sodium erythorbate		0.85
Sodium nitrite		0.25
Formula 3		
Pork jowls	55	
Whole-carcass beef	45	
Ice	40	
Salt	3	
Corn syrup	2	
White pepper		4
Nutmeg		1
Sodium erythorbate		0.85
Sodium nitrite		0.25
Formula 4		
Pork jowls	50	
Whole-carcass beef	30	
Pork trimmings (80% lean)	20	
Ice	35	
Salt	3	
Corn syrup	2	
White pepper		4
Nutmeg		1
Sodium erythorbate		0.85
Sodium nitrite		0.25

Instructions. For all four formulas, grind the beef and pork trimmings through a ¼-in. plate. Chop the beef with half the ice, nitrite, erythorbate, salt, and corn syrup to a smooth paste. Add the remaining pork, ice, and spices, chop to 56°–60°F, or until desired texture is achieved. Transfer to a stuffer and stuff into No. 25 cellulosic casings. Link at 5¼-in. lengths to give 10 to the pound finished frankfurters.

Hand-link the product on smokesticks in loops with 8, 9, 10, or 12 frankfurters to a loop, and 21 to 22 loops to a 42-in. smokestick. The smokesticks are transferred to cages and the sticks spaced to permit good air flow when the product is cooked.

A suggested schedule for processing follows:

Temperature (°F)	*Time*	*Smoke Instructions*
130°	15 min	Dampers open, smoke on
140°	15 min	Dampers closed, smoke on
160°	30 min	Dampers closed, smoke on
170°	30 min	Until 155°F temperature is reached

Cold shower for 5 min and chill to approximately 90°F. Allow to stand for 15 min minimum to dry surfaces before placing in a holding cooler. After chilled frankfurters have reached approximately 40°F internal temperature, they are peeled and packaged in 1-lb units.

Note. Introduction of continuous frankfurter lines and high-velocity smokehouses that process frankfurters in from 40 to 60 min has resulted in changes in conventional manufacturing systems. With large-volume operations pre-blending of the meat ingredients has become a standard practice. These trimmings are separated by visual inspection into fat and lean trimmings. The fat content of the lean and fat meat trimmings is determined, Table 10.1 shows the pounds of each type of trimming to give 100 lb blend with a 35% fat content. A production test run should be made to establish the processing shrink. Then appropriate moisture additions (Table 10.1) can be made on subsequent batches. Some of the continuous units process, shower, and brine chill the product for immediate peeling of the frankfurters.

Frankfurters (Milk Powder)

Ingredients	*lb*	*oz*
Regular pork trimmings	70	
Pork trimmings (80% lean)	20	
Lean beef chucks	10	
Ice	30	
Dry skimmilk	3	
Salt	3	8
Pepper		2
Paprika		2
Capsaicin		1
Nutmeg		1
Sodium erythorbate		0.85
Sodium nitrite		0.25

Instructions. Chop the lean pork and beef with half the ice, salt, sodium nitrite, and erythorbate to give a smooth paste. Add the milk powder, spices, and remainder of the ice and chop about 6 min to a

TABLE 10.1. Meat Block, 35% Fat
(lb lean/lb fat trim)

% fat content of lean trim																		
5	26/74	30/70	33/67	36/64	39/61	41/59	43/57	45/55	47/53	49/51	51/49	53/47	54/46	56/44	57/43	58/42	59/41	61/39
7	27/73	31/69	34/66	37/63	40/60	43/57	45/55	47/53	49/51	51/49	53/47	54/46	56/44	57/43	59/41	60/40	61/39	62/38
9	29/71	33/67	36/64	39/61	42/58	45/55	47/53	49/51	51/49	53/47	55/45	56/44	58/42	59/41	60/40	62/38	63/37	64/36
11	30/70	34/66	38/62	41/59	43/56	46/54	49/51	51/49	53/47	55/45	57/43	58/42	60/40	61/39	62/38	64/36	65/35	66/34
13	32/68	36/64	40/60	43/57	46/54	49/51	51/49	53/47	55/45	57/43	59/41	60/40	62/38	63/37	64/36	66/34	67/33	68/32
15	34/66	39/61	42/58	45/55	48/52	51/49	53/47	56/44	58/42	59/41	61/39	63/37	64/36	65/35	67/33	68/32	69/31	70/30
17	38/63	41/59	45/55	48/52	51/49	54/46	56/44	58/42	60/40	62/38	64/36	65/35	66/34	68/32	69/31	70/30	71/29	72/28
19	40/60	44/56	48/52	51/49	54/46	57/43	59/41	61/39	63/37	65/35	66/34	68/32	69/31	70/30	71/29	72/28	73/27	74/26
21	43/57	47/53	51/49	54/46	57/43	60/40	62/38	64/36	66/34	68/32	69/31	71/29	72/28	73/27	74/26	75/25	76/24	77/23
23	46/54	51/49	55/45	58/42	61/39	64/36	66/34	68/32	69/30	71/29	72/28	74/26	75/25	76/24	77/23	78/22	79/21	80/20
25	51/49	56/44	59/41	63/37	65/35	68/32	70/30	72/28	73/27	75/25	76/24	77/23	78/22	79/21	80/20	81/19	82/18	83/17
27	57/43	61/39	65/35	68/32	70/30	72/28	74/26	76/24	78/22	79/21	80/20	81/19	82/18	83/17	84/16	84/16	85/15	86/14
29	64/36	68/32	71/29	74/26	76/24	78/22	80/20	81/19	82/18	83/17	84/16	85/15	86/14	87/13	87/13	88/12	89/11	89/11
	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77	79

% fat content of fat trim

temperature of 52°–55°F. Stuff into No. 25 cellulosic casings and link at 5¼ in. Heat at 120°F for 30 min, raise the smokehouse temperature to 140°F for 30 min and finally 160 to 165°F until a 152°F internal temperature is reached. Cold shower for 5 min. Allow the surface to dry and place the frankfurters in a cooler at 34°–38°F. Peel and package.

Frankfurters (German Style)

Ingredients	*lb*	*oz*
Formula 1		
Beef trimmings	40	
Pork jowls	25	
Beef head meat	20	
Regular pork trimmings	15	
Ice	30	
Dry skimmilk powder	4	
Salt	3	
White pepper		4
Nutmeg		1
Garlic powder		0.25
Sodium nitrite		0.25
Formula 2		
Whole-carcass beef	40	
Regular pork trimmings	30	
Pork trimmings (60% lean)	20	
Veal	10	
Ice	30	
Dry skimmilk powder	4	
Salt	3	
White pepper		4
Nutmeg		1
Garlic powder		0.25
Sodium nitrite		0.25

Instructions. Follow instructions given for preparation of meat frankfurters.

Frankfurters (Milwaukee)

Ingredients	*lb*	*oz*
Pork trimmings (60% lean)	40	
Regular pork trimmings	35	
Cow trimmings	10	
Lean veal	10	
Pork neck bone trimmings	5	
Ice	30	
Salt	2	8
Corn syrup	1	
Sugar		8
White pepper		4
Monosodium glutamate		2

Frankfurters (Milwaukee) (*Cont.*)

Nutmeg	1
Ginger	1
Sodium nitrite	0.25

Instructions. Chop the beef, veal, and neck bone trimmings with the ice, salt, sugar, and sodium nitrite to a smooth paste. Grind the pork trimmings through a ¼-in. plate. Mix the emulsion with spices in a mixer for 5 to 6 min.

Transfer to a stuffer and stuff into No. 25 cellulosic casings. Link at 4-in. intervals. Heat at 120°F for 30 min, raise the smokehouse temperature to 140°F for 30 min and finally 160 to 165°F until a 152°F internal temperature is reached. Cold shower for 5 min. Allow the surface to dry and place the frankfurters in a cooler at 34°–38°F. Peel and package.

White Hot Frankfurter (No Nitrite Cure)

Ingredients	*lb*	*oz*
Regular pork trimmings	50	
Lean veal	25	
Whole carcass beef	25	
Ice and water	60	
Cracker meal	12	
Salt	4	
Corn syrup	2	
White pepper		6

Instructions. Grind beef and veal through an ⅛-in. plate and pork through a ¼-in. plate. Place all ingredients in the chopper and chop to a fine texture. Stuff in No. 26 cellulosic casings, link at 4-in. intervals. Hold at room temperature for a maximum of 1 hr to dry slightly. Cook in a Jourdan cooker or steam cabinet at 160°–165°F for 15 min, or until an internal temperature of 155°F is reached. Cold shower and then transfer to a holding cooler. Peel, package, and hold in a 30 to 34°F cooler.

Note. This item is quite perishable and care should be taken to prevent spoilage.

Bockwurst

Ingredients	*lb*	*oz*
Formula 1		
Veal trimmings	40	
Regular pork trimmings	40	
Beef trimmings	20	

Bockwurst (*Cont.*)

Wheat flour	3	
Salt	2	8
White pepper		4
Nutmeg		1
Fresh eggs	2 dozen	
Formula 2		
Pork trimmings (65% lean)	65	
Veal clods	35	
Fluid milk (skim or whole)	8	
Ice	4	
Salt	2	8
Sugar		4
Mace		1.5
Eggs	1 dozen	
Formula 3		
Veal trimmings	50	
Regular pork trimmings	50	
Fresh milk	12	
Onions (juice only)	3	
Salt	2	8
Sugar		8
White pepper		4
Sage		0.5
Thyme		0.5
Cardamom		0.5

Instructions. Grind the meat ingredients through a 1-in. plate and then through an ⅛-in. plate. Place in a cutter and chop for 3 to 4 min after adding the milk, salt, and spices. Stuff into casings. Chill in cooler to 26°–30°F.

Note. The product should have a smooth texture and very pale color. It is very palatable but is also readily perishable and has a short shelf life. Keep well refrigerated.

Liver Sausage and Braunschweiger

These are emulsion-type sausages that are usually water-cooked; in the case of braunschweiger, the cooked product may be lightly smoked at the end of the cook cycle. In some instances, smoked bacon is used in the product to produce a smoked flavor. Some producers call their top-grade product braunschweiger and their economy grade liver sausage.

Liver Sausage

Ingredients	*lb*	*oz*
Formula 1		
Pork livers	50	
Pork jowls	50	
Salt	2	8

Liver Sausage (*Cont.*)

Ground white pepper		4
Coriander		1
Nutmeg		1
Sodium nitrite		0.25
Formula 2		
Pork livers	50	
Regular pork trimmings	40	
Veal trimmings	10	
Fresh onions	5	
Milk powder	3	8
Salt	2	8
White pepper		4
Sodium nitrite		0.25
Formula 3		
Pork livers	50	
Jowls	30	
Veal trimmings	15	
Bacon ends	5	
Milk powder	3	8
Salt	2	8
Dry onion flakes (toasted)		8
White pepper		4
Monosodium glutamate		2
Sodium nitrite		0.25
Formula 4		
Pork livers	35	
Cooked tripe	25	
Cooked pork skins	15	
Sweet pickled ham fat	15	
Pork jowls	10	
Dry skimmilk	3	8
Salt	2	8
White pepper		4
Ground clove		1
Sodium nitrite		0.25

Instructions. For all the above formulas, grind the jowls or pork trimmings through a ½-in. plate. Grind tripe and pork skins through an ⅛-in. plate. Chop livers and other meat ingredients together with the spices, cure, salt, and dry skimmilk. Chop all ingredients to a paste or use the chopper as a mixer for several passes and then run the emulsion through the fine plate of an emulsifier. Stuff tightly into No. 3 × 32 inch moistureproof fibrous casings using a large horn, usually 1-in. diameter, with a line pressure of 35 to 70 psi. Place the sausage in a 165°F water tank for 1½ hr. Chill rapidly, preferably in a tank or truck with slush ice.

Note. Adjust inventories of raw materials so that at least 50% of the livers are fresh. When only frozen livers are used, it is well to use some fresh trimmings. Fresh livers usually result in more stable emulsions than frozen livers.

The internal temperature of liver sausage should be between 150° and 152°F. Higher temperatures may produce a bitter flavor in the finished sausage. Lower temperatures may not give the desired shelf-life.

Gray-colored liver sausage can be achieved by leaving the nitrite out of the sausage.

Liver Sausage (10 oz Unit Packs)

Ingredients	*lb*	*oz*
Pork livers	45	
Skinned pork jowls	45	
Beef trimmings	5	
Smoked bacon ends	5	
Dry skimmilk	3	8
Salt	2	8
Corn sugar	1	
Dehydrated onions		4
White pepper		4
Coriander		1
Sodium nitrite		0.25

Instructions. Grind the jowls, bacon, and beef through an ⅛-in. plate. Place the livers in the chopper and chop with the dry skim-milk, salt, sugar, spices, and cure to obtain a free-flowing paste. Add the ground meats and chop to the desired texture, usually 6 or 8 min. Liver sausage emulsion should be handled as little as possible. Transfer to a stuffer, attach a Rockford filler, adjusted to deliver 10 oz. Stuff tightly into 3 × 11-in. plastic tubes. Place stuffed and tied product into 160°F water and hold for 1 hr, or until the sausage reaches an internal temperature of 152°F.

Chill in ice water and hold overnight in a cooler or until the sausage has an internal temperature of 35°F. Dip the chilled sausage for 5 to 10 sec in 195°–200°F water to shrink the plastic film to the contracted sausage surface. This gives a tight, smooth package. Hold in 30°–34°F cooler.

Cotto Salami

Ingredients	*lb*	*oz*
Formula 1		
Beef trimmings (75% lean)	25	
Cow meat	20	

Cotto Salami (*Cont.*)

Pork cheek meat	20	
Pork hearts	20	
Regular pork trimmings	15	
Ice	10	
Salt	2	8
Sugar		12
Whole black pepper		3
White pepper		2
Sodium erythorbate		0.85
Garlic powder		0.5
Sodium nitrite		0.25
Formula 2		
Cow meat	30	
Regular pork trimmings	30	
Pork cheek meat	20	
Pork hearts	15	
Pork stomachs	5	
Ice	10	
Salt	2	8
Sugar		12
Whole black pepper		3
White pepper		2
Sodium erythorbate		0.85
Garlic powder		0.5
Sodium nitrite		0.25

Instructions. Grind the pork meat items through a ¼-in. plate and the beef through an ⅛-in. plate. Chop the beef trimmings, ¼ of the cow meat, and the pork stomachs with the ice, salt, sugar, cure, and erythorbate to a smooth paste. Mix with the spice and ground meat in a mixer for about 5 min. Hold for 6 to 8 hr at 40°F. Stuff into No. 8 × 22-in. fibrous casings.

Place six pieces to a 42-in. smokestick and space to prevent touching or crowding so good circulation of air can be obtained in the smokehouse.

A suggested schedule for cooking is as follows:

Temperature (°F)	*Time*	*Smoke Instructions*
140°	1 hr	With smoke
160°	2 hr	With smoke
170°	3 hr	With smoke
180°	1 hr	Until 153°F internal temperature is reached

Shower with cold water for 40 min. Then rinse with hot water for 10 to 20 sec to remove grease. Chill at 28°–32°F until 40°F internal is obtained. Hold at 38°–40°F.

SPECIALTY ITEMS

Specialty items are often prepared from meat products other than skeletal meat and are formed in a variety of loaf shapes: (1) rectangular, (2) traditional, (3) old-fashioned, and (4) cylindrical (if sliced and packaged at plant level). See Fig. 10.1.

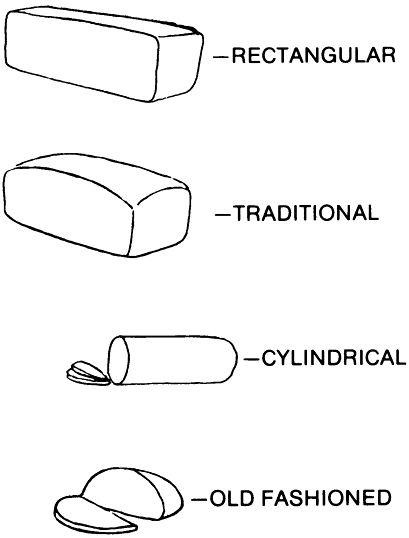

FIG. 10-1 Loaf styles.

These loaf items are some of the most nutritious products of the sausage trade and are of interest economically since they frequently utilize meat by-products to the best advantage.

Federal Meat Inspection Regulations classify loaves into two general groups: (1) meat loaves, and (2) nonspecific loaves. Meat loaves may contain no more than 3% added water and are made from comminuted meat or meat by-products. "Old-Fashioned" meat loaves come under this class and must have rounded tops. They are usually made from coarsely ground meat, cereal, seasonings, water, milk and a limited quantity of vegetables, usually onions, garlic, or tomato products. The amount of meat in old-fashioned loaves must consist of at least 65%. Nonspecific loaves have no specific requirements for composition, although they must be labeled with a statement of ingredients. Typical nonspecific loaves include "B-B-Q Loaf," "Olive Loaf," and "Pickle and Pimento Loaf."

Family Loaf

Ingredients	*lb*	*oz*
Beef trimmings (90% lean)	50	
Pork trimmings	50	

Family Loaf (*Cont.*)

Ice	30	
Wheat flour	12	
Dry skimmilk	4	
Salt	2	12
Corn syrup	1	
Chopped onions	5	
White pepper		4
Sage		2
Celery seed		1
Sodium nitrite		0.125

Instructions. Grind the beef through an ⅛-in. plate and the pork through a 3/16-in. plate. Chop the beef, ice, flour, milk powder, spices, and sodium nitrite for 2 to 3 min. Add the pork trim and chop for an additional 2–3 min.

Stuff into stainless steel loaf pans 10 × 5 × 4 in. that have been coated with lard on the inner surface. Stuff with a loaf stuffing horn on a piston stuffer with 80 lb air pressure. Stuff to top of the pan. Then level off the top of the pan with a flat knife or spatula. Cooking can be done in a bake oven or a smokehouse. The oven should be kept below 220°F. Loaves are heated to an internal temperature of 152°–155°F. In a smokehouse the following schedule can be used: 1 hr at 150°F; 1 hr at 170°; 3 hr at 190°F, or until an internal temperature of 152 to 155°F is reached.

Cool loaves at room temperatures for 2 hr, then dip in hot cottonseed oil at a temperature not to exceed 425°F. Dip for 20 to 30 sec, or until the loaf takes on a reddish-brown baked appearance. Chill to an internal temperature of 45°F. Stuff into plastic tubes 7½ × 18 in. and store at 32°–34°F.

This loaf can be prepared in No. 8 × 40-in. fibrous casings by processing in the smokehouse for 8 hr, starting at 130°F for 30 min and then raising the temperature to 150°F for 1 hr, and finally heating for 6 hr or more at 170°F. Cold shower for 40 min and then chill to an internal temperature of 42°F. Strip the casing and slice the loaf for prepackaged items. In this manner, the product can be produced in a cylindrical form and still be merchandised as a loaf item in accordance with Federal meat inspection regulations.

Veal Loaf

Ingredients	*lb*	*oz*
Lean veal trimmings	40	
Regular pork trimmings	40	
Cooked tripe	20	
Ice	45	
Dry skimmilk	12	

Veal Loaf (*Cont.*)

Fresh chopped onions	5	
Salt	3	
Mustard flour	1	
White pepper		4
Lemon extract		2
Garlic powder		1
Sodium nitrite		0.125

Instructions. Grind the meat products through a ¼-in. plate. Transfer to the chopper and chop all the ingredients to a smooth paste. Follow the instructions outlined for preparation of the family loaf.

Luxury Loaf

Ingredients	*lb*	*oz*
Formula 1		
Extra lean pork (95% lean)	80	
Cow meat	20	
Ice	15	
Dextrose	3	8
Salt	2	8
Sodium nitrate		1
Sodium nitrite		0.25
Formula 2		
Extra lean pork (95% lean)	80	
Cow meat	10	
Pork shank meat	10	
Ice	15	
Dextrose	3	8
Salt	2	8
Sodium nitrite		0.25

Instructions. Grind the cow meat and pork shanks through an ⅛-in. plate and the lean pork through a 1-in. plate.

Chop the cow meat and pork shanks with the ice, salt, sugar, nitrate, and nitrite for about 5 min to a smooth paste. Transfer to a vacuum mixer and add the lean pork. Mix under vacuum for 2 min. Hold for 24 hr at 36°–40°F. Vacuum-mix for 3–5 min. Stuff in 11 × 4 × 4-in. metal molds with parchment liners. Use a large loaf stuffing horn and a piston air stuffer with 60–70 lb line pressure. Stuff compactly and slowly from the bottom to the top of the mold. Fold the parchment liner over the top surface. Use ratchet lids for covering the mold. Place the molds in 160°F water and cook for 3½ hr, or until an internal temperature of 152°F is reached. Chill with tap water to 90°F and then place in tubs with cracked ice. Remove from molds and stuff the loaves into plastic tubes and store at 30°–34°F. This product can be processed in suitably sized fibrous casings and squared into the rectangular shape by compressing the encased product in a wire cage.

Note. The meat should be selected and trimmed with care to remove any connective tissue or tendons and any excess fat, since these items would show as particles in the loaf and detract from its quality.

Cured Beef Loaf

Ingredients	*lb*	*oz*
Lean beef	100	
Ice	5	
Salt	3	
Sugar	1	
Sodium nitrite		0.125

Instructions. Grind the beef through a ½-in. plate. Mix all the ingredients in a mixer for 5 min. Transfer to a cooler and hold for 24 hr at 36°–40°F. Grind the mix through an ⅛-in. plate, mix for 5–6 min, and transfer to a stuffer. Stuff in parchment-lined metal molds or suitable-sized fibrous casings. Heat in a water cooker to an internal temperature of 152°–155°F; usually 3½ hr at 160°F is sufficient for 4-in rectangular loaves. Chill in a tank of slush ice. Remove from molds and wrap in plastic wrappers. If product is sliced thin, it has many of the characteristics of chipped beef.

Haggis

Ingredients	*lb*	*oz*
Pork hearts	50	
Pork livers	20	
Beef suet	20	
Pork spleens	10	
Oatmeal	35	
Fresh onions	5	
Salt	2	
White pepper		6
Nutmeg		3

Instructions. Cook the hearts, livers, and spleens in 180°–190°F water. Remove the cooked items and grind with the suet through a ¼-in. plate. Chop onions to a fine pulp. Bring the broth separated from cooking to a boil and sift in the oatmeal. Stir vigorously. To the hot mass add the cooked meats, onions, salt, and spices. Stuff into No. 8 moisture proof fibrous casings and cook for 3 hr in 170°F water until an internal temperature of 160°F is reached. For a traditional product, a sheep stomach is filled and cooked. The item is highly nutritious but quite perishable. Keep chilled at 30°–34°F.

Blood Pudding

Ingredients	*lb*	*oz*
Beef blood	35	
Pork back fat	20	
Pork skins	15	
Pork snouts	10	
Pork ears	5	
Pork weasand meat	5	
Pork hearts	5	
Pork stomachs	5	
Dry skimmilk	10	
White corn meal	5	
Fresh onion	2	
Salt	1	4
Sugar	1	
Black pepper		4
Marjoram		2
Fresh garlic		1
Clove		1
Cinnamon		0.5
Sodium nitrite		0.25

Instructions. The pork ingredients are obtained from vat-cured pork. Snouts from white pigs are often separated and used in souse or head cheese. The cured pork items are cooked until tender and then ground through an ⅛-in. plate. The backfat is scalded and diced into ¼-in. cubes.

Place the ground materials in a mixer, add blood, diced fat, salt, spices, and curing salts and mix for 6 to 8 min. Transfer to a stuffer and stuff into No. 6 fibrous casings or into ring casings.

Cook at 160°F in water for 3 hr, or until a 152°F internal temperature is reached. Cold shower or chill in slush ice. Dry the surface of the product at room temperature prior to placing in 34°–38°F holding cooler.

Note. Blood can be whipped with a paddle or a bundle of small sticks to remove fibrin. Store the defibrinated blood at 36°F or lower. Salt used at 2½ lb per 100 lb blood together with ¼ oz sodium nitrite and 1 lb sugar aids in preservation.

An excellent anticoagulant for blood collection can be prepared by dissolving 3 oz sodium citrate and 3 oz salt in 1 qt water. Pour this solution into the holding container for the blood and stir gently. Store the blood in a 32° to 36°F cooler. If desired, 2 lb salt and ⅛ oz sodium nitrite can be added to the blood after chilling.

Blood and Tongue Loaf

Ingredients	*lb*	*oz*
Formula 1		
Pickled lamb or pork tongues	65	
Cured beef blood	20	
Pork back fat	15	
Dry skimmilk	12	
Fresh onions	5	
Salt	1	
White pepper		4
Fresh garlic		2
Marjoram		2
Clove		1
Formula 2		
Pickled lamb or pork tongues	35	
Cured beef blood	25	
Pickled back fat	25	
Pickled pork skin	15	
Dry skimmilk	12	
Fresh onions	5	
Salt		8
White pepper		4
Garlic		2
Marjoram		2
Clove		1
Cinnamon		0.5

Instructions. Scald and clean the tongues and cut into 1-in. cubes. Cut backfat into ¼-in. cubes. Rinse cubed back fat in water before using. This prevents the fat from sticking together. Grind the onions through an ⅛-in. plate and press garlic in a garlic press.

Place all the ingredients in a mixer and mix for 6 to 8 min. Stuff into No. 6 fibrous casings or place in greased loaf pans. Water cook for 3–3½ hr at 165°F, or until an internal temperature of 155°F is reached. Chill in ice water and transfer to a holding cooler at 34°–38°F.

Note. Back fat should be held in pickle brine prior to cubing. This hardens the fat and facilitates cutting in the cuber.

Blood Sausage

Ingredients	*lb*	*oz*
Cured beef blood	85	
Diced pork fat	15	
Fresh onions	5	
Salt	2	
White pepper		4
Nutmeg		1
Cinnamon		0.5

Instructions. Chop the onions to a fine pulp. Add diced pork fat, onions, salt, and spices to the blood. Fill No. 26 cellulosic casings. Place the filled casings in 165°F water for 30 min, or until an internal temperature of 152°–155°F is reached. Chill in ice water. Cut cooked, chilled sausage into 4-in. lengths and package.

Kiszka

Ingredients	*lb*	*oz*
Sweet pickle ham skins	45	
Cured pork snouts	25	
Pork liver	15	
Cured lips	5	
Tripe	5	
Cured beef blood	5	
Water	50	
Barley	25	
Onions	5	
Salt	1	
Pepper		4
Thyme		1
Nutmeg		1
Marjoram		1

Instructions. Grind the cured ingredients through an ⅛-in. plate. Chop the liver, onions, and spices with the ground materials to a smooth paste. Sift barley into boiling water and stir. The barley will swell and absorb most of the water. At this time, add the lard and stir until the lard is well incorporated. Add the blood and chopped paste and stir until the mass is mixed.

Stuff into beef rounds and tie into rings or stuff into No. 30 fibrous casings. Place the sausage in boiling water for 20 to 25 min. Remove from cook tank. Allow to dry at room temperature for at least 30 min and place in a refrigerator at 32°–38°F.

Note. Buckwheat or rice may be substituted for the barley.

Pickle and Pimiento Loaf

Ingredients	*lb*	*oz*
Pork trimmings (70% lean)	60	
Veal trimmings	30	
Beef trimmings (85% lean)	10	
Ice	40	
Dry skimmilk	12	

Pickle and Pimiento Loaf (*Cont.*)

Sweet pickles	5	
Pimientos	5	
Fresh onions	5	
Salt	3	
Dextrose	1	
White pepper		4
Marjoram		1
Sodium erythorbate		0.85
Sodium nitrite		0.25

Instructions. Grind the meats through an ⅛-in. plate. The pickles are passed through a ¼-in. plate and the pimientos through a ½-in. plate of a vegetable chopper. Chop the meat ingredients with the onions, spices, salt, cure, milk powder, and ice to give a smooth paste. Add the pickles and pimiento and run for two or three revolutions of the bowl to get a good mix.

Stuff into parchment-lined metal molds or into No. 7½ easy-release fibrous casings for in-plant-slicing. The product in molds is water-cooked at 165°F until an internal temperature of 152°–155°F is reached, usually 3½–4 hr. The product in casings is best cooked in a high-humidity, high-velocity smokehouse.

The product is well chilled, the casing removed by stripping, and the loaf sliced. A loaf temperature of 28°–30°F facilitates handling while slicing. Loaf items in molds are removed after chilling and can be stuffed into a cellulosic or plastic film for shipping and display.

Baked loaves can be prepared in the mold by heating at 225°–250°F, until a 155°F internal temperature is reached. They are then handled as are water-cooked loaves.

Note. Pimientos are sweet bell-shaped Spanish peppers and should not be confused with pimento which is related to allspice.

Olive Loaf

Ingredients	*lb*	*oz*
Lean veal	50	
Pork trimmings (50% lean)	40	
Beef trimmings (85% lean)	10	
Ice	45	
Dry skimmilk	12	
Stuffed olives	6	
Salt	2	12
Sugar	1	
White pepper		4
Marjoram		1
Sodium nitrite		0.25

Instructions. Grind the meat ingredients through a ¼-in. plate. Chop the ice, milk powder, salt, sugar, spices, and cure for 6–8 min to a smooth paste. Drain the olives. Sprinkle the drained olives with a light layer of powdered gelatin and work into the emulsion with a large spatula or paddle. Stuff into loaf pans or into No. 7½ easy-release fibrous casings. Process as indicated for pickle and pimiento loaf.

MISCELLANEOUS SAUSAGES

There are a number of sausages which do not fit the earlier classification system. These include scrapple, souse, head cheese, mortadella, and linguica.

Scrapple

Ingredients	*lb*	*oz*
Cured pork head meat	65	
Cured pork skins	20	
Pork livers	15	
Water	65	
Corn meal	35	
Salt	2	8
Pepper		4
Sage		2
Nutmeg		1

Instructions. Cook the head meat, skin, and liver in water in a steam-jacketed kettle. Remove the meat products and grind through a ⅛-in. plate. Add the ground meat products back and continue cooking in boiling water. Stir in the corn meal, salt, and spice with a paddle and continue to cook for at least 30 min to a thick consistency. Pour the sausage into greased molds or into No. 8 fibrous casings and chill rapidly. Hold overnight. Slice in thick slices and package.

Souse

Ingredients	*lb*	*oz*
Cured pork tongues	35	
Cured pork snouts (white pigs)	20	
Cured pork cheeks	20	
Cured lean ham trimmings	15	
Cured pork lips	10	
Pickles (diced)	6	
Pimientos	6	
High-bloom gelatin	3	8
100-grain vinegar	3	
Salt	1	

Souse (*Cont.*)

Whole pepper	2
Whole cloves	2

Instructions Place the meat ingredients in sufficient water to cover. Bring the water to a boil and simmer until tender. Remove the cooked meat and grind through a 1-in. plate. Reheat the broth with the added spices and then filter through cloth to remove particles of meat and spice. To 2 gal broth, add the vinegar, salt, and gelatin. Reheat this mixture to 165°F and pour over the meat mass to which the pickles and pimientos have been added. Chill in cooler overnight. Remove from molds and wrap in cellulosic or plastic tubes. Store at 32° to 36°F.

Head Cheese

Ingredients	*lb*	*oz*
Cured pork snouts (white pigs)	20	
Cured pork lips	20	
Cured pork hearts	20	
Cured pork cheek meat	15	
Cured pork skins	15	
Cured pork ears	10	
Broth from cooking water	45	
Onions	5	
Gelatin	4	
Vinegar	3	
Salt	1	
Mustard		8
White pepper		4

Instructions. Place the various meat ingredients in separate cooking nets. Cover with water and cook at 170°–180°F until tender, usually 2–3 hr. Hearts usually require longer heating than the other items. Grind the onions, ears, and skins through a 1/16-in. plate. Cut the snouts, lips, hearts, and cheeks into 3/4-in. pieces. Place the meat ingredients in a mixing vat and add the heated broth with the spice, salt, gelatin, and vinegar. Stuff into pork stomachs or into No. 60 fibrous casings. Cook at 165°F for 2½ hr and then chill in ice water. Store at 35°–40°F.

Mortadella

On the world market mortadella is possibly the largest volume type of sausage produced. It can be either beef, beef and pork, and in some instances may contain turkey, chicken, goat or mutton. It is composed of ground meat, to which cubes of cured fat, and at times, olives or pistachio nuts are dispersed throughout the meat mass. In some marketing areas, the green pistachio nut is a traditional ingredient. Usually, about 1 lb of nuts to 100 lbs of sausage is dispersed into the sausage mix.

Mortadella can be fermented, dried, smoked or cooked, and is produced in units ranging from 1½ ounces to 120 lbs. It is encased in hog casings, collagen casings, beef bungs, in fibrous casings, or in beef bladders. Beef bladders were original types of casing used for mortadella sausage, however, modern engineering practices have resulted in fibrous casings becoming the casing of choice for many producers of mortadella.

Mortadella

Ingredients	*lb*	*oz*
Formula 1. Beef		
Beef trimmings (85–90% lean)	75	
Beef navels (50% lean)	25	
Ice	15	
Salt	2.5	
Sugar	1.0	
Pepper (black)		4
Ginger		1
Mace		1
Coriander		1
Sodium nitrate		0.5
Sodium nitrite		0.25
Sodium ascorbate		0.75
Formula 2. Beef and Pork		
Beef trimmings (85% lean)	80	
Pork fat diced (¼-in. pieces)	20	
Ice	15	
Salt	2.5	
Sugar	1.0	
Pepper (black ground)		4
Sodium nitrite		0.25
Sodium ascorbate		0.75
Formula 3. Pork		
Pork shoulder (90% lean)	75	
Pork fat-diced (¼-in. pieces)	25	
Ice	10	
Salt	2.5	
Sugar	1.0	
Pepper		4
Sodium nitrite		0.25
Sodium ascorbate		0.75

Instructions. The lean meats are ground through a ¼-in. plate. The navels or fat beef are passed through a ⅜ in. plate. Pork fat is cubed with a dicer or passed through a ⅜-in. plate. If preferred, cured beef fat or pork fat may be used. The lean meat is mixed with the ice, salt, sugar, spices, and curing salts in a suitable mixer. The ground or diced fat is added last so as to minimize smearing of the fat. In some instances, the lean is chopped to give a smooth paste and the fat particles are dispersed into the paste in a suitable mixer. The mixture is stuffed into the desired size casings.

The most common size is a No. 8 fibrous casing about 48 in. in length. This gives a product of weighing about 25 lb. If No. 1 fibrous casings are used, the sausage is linked to give a product weighing 1½ to 2 oz each. The product in No. 8 fibrous casings is transferred to the smokehouse. Smoke is introduced for the first hour at 150°F, and the temperature is then raised to 168°–172°F for 7 hr or until an internal temperature of 158°F is reached. The product is given a cold shower for approximately 30 min being sure to leave some residual heat in the product to assure good surface drying prior to placing it in the holding coolers. It is then held for 8–10 hours at 34°F prior to slicing, or prior to shipment as chunks or as intact the sausage.

One operator in France reported that mortadella 4.75 in. in diameter and 167 in. long are made for chunking. The finished sausage weighs approximately 112 lb. The chunks are cut into approximately 12-in. lengths and are vacuum packed for the retail trade. The chunks are sliced at the store level for the consumer.

Note. When olives or pistachio nuts are dispersed into the sausage meat, it is desirable to pre-soak the olives or nuts in a salt brine that is in balance with the sausage mix. For example, a 5–6% salt brine is a suitable level for use and the olives or nuts are soaked in the same concentration of brine for 2 hr prior to draining and adding to the sausage mix.

Linguica (Portuguese Sausage)

This sausage is prepared as either a fresh or a smoked sausage.

Fresh Linguica

Ingredients	*lb*	*oz*
Pork trimmings (65% lean)	100	
Salt	2.5	
Wine vinegar	1.0	
Wine white	1.0	
Dextrose	1.0	
White pepper		2
Garlic		0.25
Sodium nitrate		0.25
Sodium nitrite		0.25

Instructions. Grind the lean trimmings through a ¼-in. plate. Mix with the salt, sugar, pepper, garlic, nitrite, and nitrate for 3 min in a mixer. Add the vinegar and wine and continue to mix for an additional

2 min. Stuff into sheep or hog casings depending on the desired size. Link or coil the sausage as desired.

Notes. Keep refrigerated at 25°–28°F. The product must be cooked before eating.

Smoked Linguica

Ingredients	*lb*	*oz*
Pork shoulders (boned picnics) (65% lean)	100	
Salt	2	
Wine vinegar	1	
Wine white	1	
Dextrose	1	
Black pepper ground		2
Ginger		1
Garlic		0.25
Sodium nitrite		0.25

Instructions. Grind the shoulder meat through a ¼-in. plate. Add the salt, dextrose, pepper, ginger, garlic, and sodium nitrite to the meat in the mixer and then add the vinegar and wine as the mixing proceeds. Mix for 5 min.

Transfer into stuffer and stuff into cellulosic, collagen, or animal casings of suitable size, usually a 23 mm diameter casing is used. Link into 5-in lengths. Hold encased linked product in the 45°F cooler for 8 hr. Transfer to smokehouse and smoke with a dense smoke for 1 hr at 130°–140°F with dampers partially opened to permit drying. Continue to heat *without* smoke at 150°–155°F or until product acquires an internal temperature of 140°–142°F. Cold shower for 2 to 3 min, allow surface to dry. The cellulosic encased product is chilled, peeled, and packaged in unit packages. Collagen encased products are cut and packaged in unit packages. The animal casing product is used for bulk or catch weight units.

SUMMARY

The sausage art is yielding to technology as production moves from small back of the store shops to large 100,000 lb per day operations. While the principles of manufacture are essentially the same for both, a considerable number of problems based on the volume or bulk of material and the scheduling and handling of this material have arisen. Successful sausage production now depends on selection of proper raw materials, controlled processing, and uniformity of workmanship. This combination will produce superior sausages.

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11

Casings, Seasonings, Extenders and Additives

CASINGS

Casings are used to make most sausages as well as some other processed meats. They determine sausage sizes and shapes. Casings may serve as processing molds, as containers during handling and shipping, and as merchandizing units for display. Casings must be sufficiently strong to contain the meat mass but have shrink and stretch characteristics that allow contraction and expansion of the meat mass during processing and storage. Casings must not only be able to withstand the forces produced during stuffing but also the forces of linking or closure.

Years ago, sausage production was limited by the amount of available animal intestines. Since the advent of cellulosic casings, sausage production is limited only by the available meat supply. Originally, animal casings played an important role in establishing sausage production techniques in the United States. Today, cellulosic casings are the major types used.

Casings for the meat industry are made of two basic materials, cellulose and collagen. Four specific types—animal, regenerated collagen, cloth, and cellulosic casings—are produced from these basic materials.

Animal Casings

The gastrointestinal tract from the gullet to the anus is used for casings. Bladders are used for special types of sausage. The structures are washed, scraped, and treated with chemicals to remove soluble components. The various anatomical structures, such as the esophagus, stomach, small and large intestines, appendix, and rectum, are all separated, cleaned, salted, and graded as to size and condition, and packaged in suitable containers for shipment and storage.

The commercial designation for casings is somewhat different from the anatomical characterization. Commercial terminology is shown in Table 11.1.

Sheep casings average 30 yards of rounds. Ideally the whole casing is

A. M. Pearson et al., *Processed Meats*

TABLE 11.1. Animal Casings

Casing	Source
Rounds	Small intestine of cattle, sheep, goats, and pigs
Runners	Small intestines of cattle
Middles	Large intestines of cattle and pigs
Beef bungs	Caecum (blind gut)
Hog bungs	End of the intestinal tract, usually 5–6 ft of intestines, starting from the anus
Caps	Caecum or blind gut of the hog
Weasands	Esophagus of cattle
Bladders	Urinary bladder of cattle or hogs
Stomachs	Hog stomach, often called maws
Small casings	Small intestines of hogs, sheep, or goats

coiled from one strand. However, during cleaning and handling some breakage may occur and the final coil may contain several strands. Casings under 18 mm diameter are listed as narrow, and the others are graded from 18 to 20, 20 to 22, 22 to 24, and over 24 mm. Small casing diameters are given in millimeters and lengths in feet. This practice has carried over into the cellulosic and regenerated collagen casing industry.

Properly prepared animal casings may return up to 25% of the value of the live animal. Much of the preparation requires hand labor and skills that are not readily available in large urban areas of the world today. The high price and relatively limited supply of animal casings has been a factor in the development of substitute casings such as cellulosic and regenerated collagen.

Examples of some typical sausage products manufactured in animal casings are shown in Figs. 11.1 and 11.2.

Products in animal casings cost more, but certain products require them. Animal casings are usually edible so that the consumer generally eats the casing along with the product. However, animal casings are less uniform in size, tend to be more fragile, and require more care in stuffing. The higher cost of animal casings coupled with a slower rate of stuffing contribute to a higher cost for products stuffed in this type of casing. Improvement in the characteristics of animal casings has resulted from better manufacturing practices along with more careful grading and sizing and has helped to maintain demand for animal casings. Generally speaking, only high quality products are put in animal casings, because of their higher unit cost. Most pork sausage and certain semidry and dry sausages are traditionally stuffed into either natural animal or regenerated collagen casings, which are manufactured from collagen derived from animal hides.

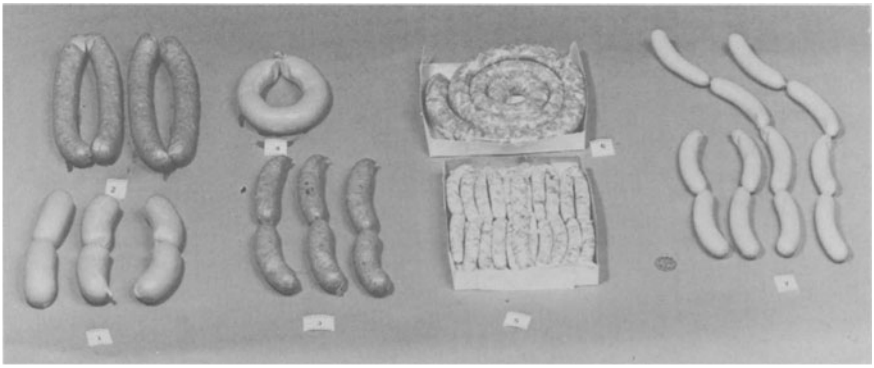

FIG. 11-1. Small sausages in hog and sheep casings. 1. Knockwurst in hog casing; 2. Polish sausage in hog casing. 3. Thuringer in hog casing. 4. Ring bologna in beef casing. 5. Pork sausage links in sheep casing. 6. Country style or rope pork sausage in hog casing. 7. Frankfurters in sheep casing.

Preflushed animal casings, especially sheep and hog casings, packed in a brine solution are available on the market. Although preflushing should theoretically make them ready to use, before using them for fresh sausages it is advisable to flush them again to remove any adherring impurities and help to prevent color problems. Another innovation in sheep and hog casings has been development of pretubed casings, which can be easily transferred from the plastic tube to the stuffing horn. Before use it is advisable to soak them in warm water to remove any salt adherring to the casing. The pretubed casings have a decided advantage in ease of using and speed of stuffing.

Regenerated Collagen Casings

Regenerated collagen casings have many of the physical properties of animal casings and the uniformity and cleanliness of cellulosic casings.

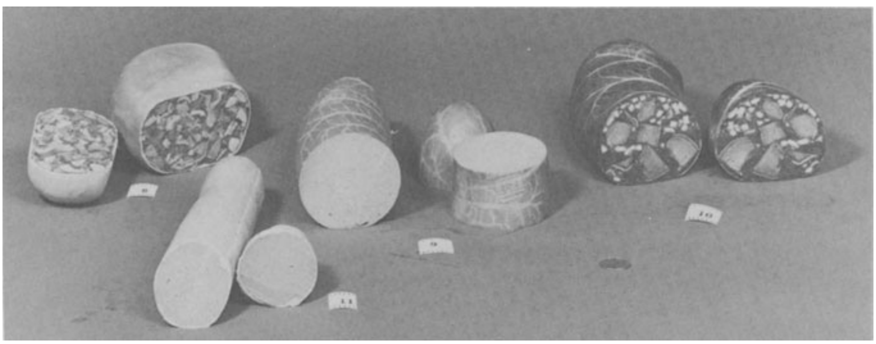

FIG. 11-2. Large sausages and specialty items in animal casing. 8. Head cheese in a hog stomach. 9. Bologna in a beef bung. 10. Blood and tongue sausage in a beef bung. 11. Liver sausage in a sewn hog bung.

Collagen casings are prepared from a suitable collagen source such as the corium layer of beef hides. The corium is extracted with an alkaline solution to remove the soluble components and washed with potable water. The collagen is then swollen with acid to give a viscous mass of acid collagen that is pushed through an annular die to form a tube. The tube is fixed by moving it through an alkaline bath, and the neutralized collagen returns to a reasonable approximation of its original state. The tube is dried and cut to size. For small sausage products, it is shirred into sticks in the same manner as small cellulosic casings. The small casings are edible and are used for fresh pork sausage links. Large collagen casings for other types of sausage are often treated with aldehydes to cross-link the collagen and increase the strength of the casing. This process makes the casing tough so it must be removed from the sausage before being eaten by the consumer.

Regenerated collagen casings are generally more uniform in size and strength than natural animal casings and are used for the same products. Although their cost is higher than cellulosic casings so that products stuffed into collagen casings tend to be higher priced than those in cellulosic casings, the increased strength of the aldehyde-treated collagen extends their versatility and makes them competitive with cellulosic casings. Since collagen casings are manufactured, they can be made in a wide variety of sizes.

Cellulosic Casings

Cellulosic casings include those made from cotton bags and those derived from processed cotton linters. Cloth bags made from various sizes of cotton thread have a small but well defined acceptance for fresh pork sausage, smoked sausage, and some specialty items such as Taylor roll. Cloth bags have been used since the Civil War. Horsford suggested their use as substitutes for animal casings in his report on the Army Ration of 1864.

Cloth bags give a high degree of uniformity to the encased product. One-, 2-, and 5-lb bags are tightly stuffed with ground pork in such a manner that some of the fat oozes through the seams and mesh of the bag. This degree of tight stuffing reduces air pockets in the product. When the bag is smoked at slightly elevated temperatures the oozed fat melts and seals the surfaces, acting as an impermeable coating which retards drying out of the sausage during storage.

Cotton linters are a fine fuzz-like material that is removed from cottonseed after the cotton fiber and seed have been separated at the cotton gin. Linters are an excellent source of high-grade alpha-cellulose. Linters are cleaned mechanically, cooked in dilute alkali to remove soluble components, and washed to remove any traces of salts. The resulting cotton has a degree of purity rarely attained in cellulosic materials. This chemical cotton it treated with caustic to produce alkali cellulose, a moist, granular white material. Mixing this with carbon disulfide results in formation of a yellow-orange viscous mass called cellulose xanthate. The xanthate is mixed with a dilute caustic solution and filtered; the resulting liquid is viscose solution. Viscose is extruded through nozzles into an acid solution and the cellulose is regenerated as the carbon disulfide is split from the complex. Wall thickness and tubular diameter can be controlled by the extruder. These finished tubes or casings are composed of pure cellulose, food-grade glycerine, and water.

Advantages of these tubes for sausage casings are their uniformity, cleanliness, and ease of handling. They can be printed or pigmented to give an attractive appearance for retail displays. Cellulosic casings are available in many sizes and types; however, they fall into four basic subdivisions.

Small Cellulose. Small-diameter cellulosic casings are most often supplied as shirred sticks, varying from 40 to 160 ft in length. Existing mechanical stuffing equipment stuffs these tubes at a rate of 250 to 300 ft/min. After processing, the small cellulose casings are removed from the sausage at the manufacturing plant as a convenience for the consumer.

Large Cellulose. Large-diameter casings are chemically identical with small casing tubes. Large cellulosic casings are supplied in flat bundles of 100 pieces. They must be soaked in water prior to use. The soaked casing is readily stretched, and on stuffing and tying the encased product acquires the characteristic sausage shape of a cylinder with hemispheral ends. A variety of bologna and large sausage products prepared in this manner are merchandized with the casings intact, or the casings may be removed at the retail level.

Fibrous. Fibrous casing is prepared from a formed cellulosic matrix to which regenerated cellulose has been added. The resulting tubes are quite strong and very uniform when stuffed. Their primary use is for production of sausages for slicing. A special type of fibrous casing is the so-called easy-release; these are similar to regular fibrous casings except they have been treated internally to facilitate their removal from large sausages. Another type of fibrous casing is covered with a plastic coating to give a moistureproof barrier. This is often used with water-cooked items such as liver sausage. The plastic coating on moisture-impermeable fibrous casings also serves as a barrier to oxygen.

Dry Sausage Fibrous. Dry sausage fibrous casings are manufactured in such a manner that they adhere to the sausage surface. This is important for the preparation of dry and semidry sausages.

Several typical sausages produced in cellulosic casings are shown in Fig. 11.3.

The great variety and range in the size of casings give meat pro-

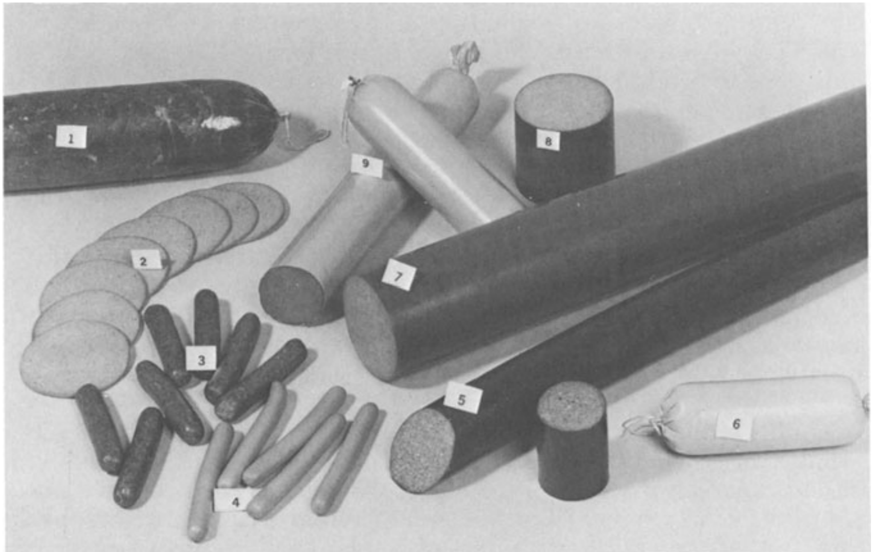

FIG. 11-3. Sausages manufactured in cellulosic casing. 1. New England sausage in large cellulosic casing. 2. Bologna slices from bologna in fibrous casing. 3. Smoked pork sausage links prepared in small cellulosic casing. 4. Skinless frankfurters prepared in small cellulosic casing. 5. Summer sausage in fibrous casing for slicing. 8. Chunk bologna in fibrous casing. 9. Liver sausage in moisture-proof fibrous casing.

cessors a great number of choices to fit market preferences. Most processors use not only various sizes and shapes but also a number of different types of casings in production of different products.

CLIPS AND THREAD CLOSURES

For closing sausage casings, a soft cotton thread from 2 to 16 ply is often used; 2-ply is used for frankfurters and other small sausages while 12- to 16-ply thread is used for bologna, salamis, and other large sausages.

Large sausage casings are usually tied while dry, and then soaked prior to stuffing. The stuffed casing is tied wet. Metal clips are used for the first closure on dry large cellulose casings and a string is used for the second closure. However, fibrous casings, because of their strength, can be clipped at both ends, either in the dry or wet state.

Figure 11.4 shows a variety of unstuffed cellulosic casings along with clips and ties that are used for closing them.

SPICES AND CONDIMENTS

Spices are aromatic substances derived from vegetative plants or herbs. Various parts of the plants are used to produce different spices.

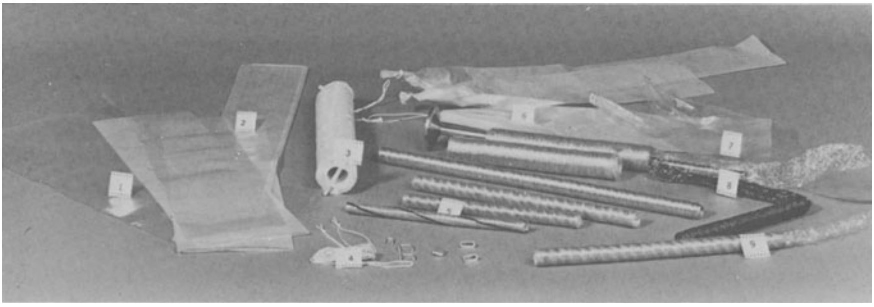

FIG. 11-4. Types of cellulosic casing, clips, and ties. 1. Large cellulosic casings used for bologna and other large sausages and smoked meats. 2. Fibrous casings used for slicing products; casings available in moisture-proof, easy release, and dry sausage types. 3. Shirred fibrous casings used for various chub sausages; available in types described under 2. 4. Butcher thread, hanging ties, and clips. 5. Shirred small cellulosic casings from 55 to 160 ft in length and 14 to 40 mm in diameter. Available with or without stripes and either uncolored or colored with a self-coloring food dye. The stripes are for product identification and as an aid in some peeling operations where the plain casings may present some difficulty in recognizing peeled from unpeeled product. 6. Clipped fibrous casings. 7. Clipped large cellulosic casings. 8. Self-coloring shirred cellulosic casing with a portion of the casing pulled from the intact shirred strand. 9. Uncolored shirred cellulosic casing with a portion of the casing pulled from the intact shirred strand.

For example, cloves come from the flower bud, nutmeg and pepper from the fruit, mace from the aril (external fleshy covering of the seed), cinnamon from the bark of a tree, and ginger from the rhizome or underground stem. Cardamon, coriander, and mustard are derived from aromatic seeds. The aromatic properties of the spices are found in the volatile oils and oleoresins. The oleoresins include the volatile oils in combination with the plant resins. The aroma and flavor of spices are attractive to man and have long been used as seasoning ingredients for foods, especially for meat products. The amount of volatile oils and oleoresins that will replace 100 lb of some ground spices is given in Table 11.2.

Spices contribute so much to sausage flavor that standardization is necessary to control seasoning formulations. Besides contributing to flavor, spices provide, in some instances, bacteriostatic and antioxidant properties. Either natural spices or the oils and oleoresins extracted from them may be used for flavoring sausages. Oils and oleoresins are solvent-extracted and transferred to a salt or sugar base. This mixture is identified as a soluble spice. As an example, black pepper contains an oil and oleoresin accounting for 5–12% of the content of the peppercorn. Pepper also contains a nitrogenous base, piperine, which is the characteristic tang or bite principle in black pepper. The piperine is usually transferred or extracted with the oleoresin fraction and may be as much as 8% of the weight of the peppercorn. Incorporation of the oleoresin at a predetermined level

TABLE 11.2. Approximate Quantities of Essential Oils and Oleoresins Required to Replace 100 lb of Some Ground Spices

Spice	Essential oil (lb)	Oleoresin (lb)
Allspice	2.5	6.0
Caraway	2.8	6.0
Cardamon	1.8	—
Celery Seed	2.0	5.5
Coriander	0.7	3.0
Dill Seed	3.2	4.5
Ginger	0.3	3.5
Mace	5.0	7.0
Nutmeg	5.5	7.5
Marjoram	0.4	2.2
Parsley Seed	2.9	4.5
Black Pepper	1.1	5.6
Sage	2.0	4.0

such as 4% in a sugar or salt base permits control of the pepper used in sausage.

Soluble spices are frequently used with canned meats, whereas natural spices are used most frequently for dry or semidry sausages. Canned meats made with natural spices may darken when heated as a result of the presence of other components in the spice, such as anthocyanins and flavones. Soluble spices are low in these compounds and give a brighter appearance to canned meat products.

Natural spices may at times acquire a high bacterial content by their very nature and because of the collection and storage conditions to which they are subjected. Some type of sterilization of natural spices is usually desirable.

The meat industry is reported to be the biggest single user of spices, black pepper being the largest single item used. Others used include allspice, basil, bayleaf, cardamon, cloves, ginger, mace, nutmeg, mustard, paprika, pimento, cayenne pepper, white pepper, caraway, coriander, celery seed, cumin, marjoram, thyme, savory, sage, anise, cinnamon, capsicum, onion, garlic, sesame, and fennel.

Spices may be used whole, cracked, or ground. Some spices are rubbed to disintegrate the structure, and others are finely milled. White pepper is used in products where black pepper particles may detract from appearance of the sausage, such as in veal sausage or light-colored loaf items. Spices are a small portion of the total ingredient cost of sausages.

Technological descriptions of spices are available in specialized food handbooks or in the U.S. Dispensatory. The Dispensatory lists the botanical source of a spice and its chemical composition; it also provides some information on the biology of the specific plants associated with the spices.

To assure proper control of the flavor complex, a good procedure is to prepare a sausage with a spice mixture and evaluate the product with a trained taste panel. While chemical standards are helpful, the final result depends on flavor or taste, which requires a periodic review of the product line by taste panels. It is also possible to evaluate spices by analyzing the volatiles using gas liquid chromatography. This procedure is often used to characterize spices and to standarize the mixtures of essential oils and/or oleoresins.

ADDITIVES

The processing, handling, and storage of sausages for today's markets has required the use of additives to meet the demands of modern consumers. Some of the common additives are water or ice, curing salts, and chemical stabilizers such as antioxidants. All additives should be food-grade quality. The Food Chemical Codex is a good reference for the quality requirements of these items.

Ice or Water

Water or ice added to the meat mass provide considerable functional qualities. The ice or water chills the meat during the chopping or mixing operations, which permits longer and more efficient churning of the meat mass without mechanical overheating. This is accomplished by lowering the initial temperatures and by lubricating the meat mass. Added water aids in dissolving sodium chloride and curing salts to give better distribution in the mass. Of equal importance, water imparts fluidity to the emulsion or meat mixture that aids in proper filling of the casings. Texture and tenderness of the finished sausages are markedly affected by the added water content.

Salt

Salt for sausages must be of food-grade quality. Salt (sodium chloride) serves three functions in sausage: (1) it dissolves in water to form a brine which acts to retard microbiological growth; (2) it aids in solubilizing the myosin-type proteins of comminuted muscle for emulsifying the fat in emulsion sausages; and (3) it contributes to basic taste characteristics.

Curing Salts

In the general concepts of curing or preservation all the additives contribute to preservation. However, specifically, the term "curing salt" refers to sodium or potassium nitrate and nitrite. These ingredients are added so that no more than 200 ppm sodium nitrite will be present in finished sausages. Some exceptions have been made for special products, but the trend is to control and possibly reduce the presence of these compounds to a workable minimum.

Nitrates and nitrites are discussed in Chapter 3. However, it may be well to emphasize the importance of nitrite in sausages. Nitrite used at the level of ¼ oz per 100 lb will result in 156 ppm nitrite in the product. This small quantity of nitrite, in combination with moisture level, pH, added salt, and final internal processing temperature, has a general bacteriostatic effect in the finished sausage. Nitrite produces a characteristic flavor. It imparts an antioxidant effect and protects the cooked products against development of warmed-over flavor.

The formation of a characteristic cured color in meat is often indicated as the primary need for curing salts, but this is not really true. The red or pink cured color becomes an indicator showing that the proper sequence of events has been satisfactorily carried out. Besides acting as an indicator of initial acceptable quality, color also serves as a signal when incipient spoilage is under way or when active spoilage has occurred. The spoiled product will discolor. It is common to note off-flavor and off-odors when the normal cured color changes to gray or brown. More details are given in Chapter 3.

Ascorbates-Erythorbates

The ascorbates and the erythorbates are closely related chemicals that can be used interchangeably in sausage mixes. They are active reducing agents that react with nitrite to give nitric oxide. In the acid form they must be used cautiously in making solutions, since nitric oxide gas in concentrated form is toxic. These compounds ensure development of the desired color in cured meats. A very specific role of ascorbic acid or its salt is its action in limiting the formation of green discolorations that sometimes occur under the metal smoke sticks. Erythorbate does not have this property.

Sugars

The use of sugars in the curing of meat is common. However, in most instances, sugar is used as an adjunct to provide flavor, mask the salt flavor, or to provide a reservoir for an acid-forming substance. Sugars are used at levels from 8 oz to 2 lb per 100 lb of meat. A variety of sugars, such as sucrose, corn syrup and solids, dextrose, and sugar derivatives such as sorbitol, are used.

Sugars in some of the sausage mixes are important to acid formation so the proper pH of the sausage product is developed and maintained. This is especially important for dry and semidry sausages.

Phosphates

Sodium acid pyrophosphate has been permitted in sausages in United States as a cure accelerator. It is allowed at a level of 0.5% in the finished product. It accelerates development of cured color in rapid processing of bacon, frankfurters, or bologna by lowering the pH rapidly by about 0.2–0.3 units during the initial stages of the operation. It has been shown to be especially helpful during processing of frankfurters in continuous cookers.

The alkaline polyphosphates, which include sodium tripolyphosphate, sodium hexametaphosphate, and tetrasodium pyrophosphate, either alone or in various combinations not to exceed 0.5% in the finished products, have recently been approved for use in sausages. Some of the potassium phosphates have also been approved for the same purposes. The alkaline phosphates not only increase the water-binding capacity as explained in Chapter 3, but they also increase the fat emulsifying capacity of the myofibrillar proteins. The increase in emulsifying capacity is the result of the polyphosphates solubilizing and dissociating actomyosin into actin and myosin, which in their dissociated forms can emulsify more fat. The increase in water binding occurs as a consequence of the polyphosphates acting as polyelectrolytes to increase ionic strength. This frees some of the negatively charged sites on the proteins so they can bind more water. The action of the polyphosphates in raising the pH also improves the water-binding capacity. The polyphosphates also decrease the purge in vacuum packaged products and improve yields. However, if the bacterial count of sausages containing polyphosphates becomes sufficiently high to increase the pH, the amount of purge in the packages containing the polyphosphates will be greater than that in similar sausage prepared without added phosphates. Another advantage of adding alkaline polyphosphates in sausages is related to their ability to chelate divalent cations, thus aiding in preventing autoxidation.

There are two disadvantages to adding alkaline polyphosphates to sausage. (1) They can impart a soapy flavor to the products when added at the legal limit permitted. (2) They may produce a rubbery texture. The latter problem is more likely to occur in products containing a high proportion of lean to fat, with overworking apparently causing the rubberiness. Consequently, it is frequently advisable to decrease the amount of alkaline polyphosphates used in the formulation, especially in high quality lean sausages where overworking is a more critical problem.

Glucono-δ-lactone (GDL)

GDL is also a cure accelerator and speeds up development of cured meat color. It is permitted at a rate of 8 oz per 100 lb of meat. At this level it will reduce the pH of the batter by about 0.2–0.3 units, which accelerates the conversion of the meat pigments to their desirable forms. It is valuable during rapid processing, especially in continuous processing.

GDL is also permitted in semidry and dry sausages at a level of 1%, where it reduces the pH by about 0.5. The rapid drop in pH aids in controlling the outgrowth of meat spoilage organisms until fermentation occurs and takes over this function. Dry and semidry sausages containing GDL have a biting acid taste, thus connoisseurs of these products prefer those made in the conventional manner without added GDL. Although color development also occurs more rapidly when GDL is added to semidry and dry sausages, this is probably not an important function since there is adequate time for cured color to develop in these products.

Acids and Liquid Smoke

The use of acids and liquid smoke has become popular especially for small sausages such as frankfurters. The acid is sprayed prior to smoking or cooking. It reduces surface pH of sausages and either coagulates proteins at the surface or permits coagulation at a lower temperature. Usually the use of an acid spray gives a better surface and helps development of surface color. Almost any food-grade acid can be used. Acetic acid or vinegar is used extensively. However, they are volatile and the odor is objectionable to some individuals. Volatile acids can accumulate on equipment by condensation and corrode the trackings, trolleys, and other areas in the plant. If an acid spray is used primarily for improving peelability, an alternative is the use of specially treated cellulosic casings.

Liquid smoke has been used for 100–150 years. However, the present products are better controlled than soot and chimney tar extracts described in the older literature. Liquid smoke, when sprayed, dipped, or atomized onto sausage surfaces, imparts flavor, improves color, and aids peeling in some instances. Because of recent demands for improving environmental quality, liquid smoke is finding increased usage. More details on the use of liquid smoke are presented in Chapter 4.

BINDERS AND EXTENDERS

There is a wide variety of nonmeat products that meat processors can incorporate into sausages within the guidelines allowed under USDA meat inspection regulations. These products are referred to as binders or extenders and less frequently as fillers, emulsifiers, or stabilizers. They are added to meat formulations for one or more of the following reasons: (1) to reduce formulation costs, (2) to improve cooking yield, (3) to improve slicing characteristics, (4) to improve flavor, (5) to increase the protein content, (6) to improve emulsion stability, (7) to improve fat binding, and (8) to increase water binding. It should be borne in mind, however, that few if any of these additives have as good functional properties as high quality lean meat. The content of these materials permitted in sausage products is controlled by federal meat inspection regulations. Individually or collectively, up to 3.5% of cereal, starch, vegetable flour, soyflour, soy protein concentrate, nonfat dry milk, and calcium-reduced nonfat dry milk are permitted in finished sausage products. Isolated soy protein, however, is restricted to 2%. Sausages containing more than 3.5% of these nonmeat ingredients or more than 2% isolated soy protein are referred to as imitation, and must be labeled as such. For meat products known as loaves, federal inspection regulations recognize two different types. Regulations governing the amount of extender materials allowed in finished products differ depending on the type loaf. Products identified as meat loaves are restricted to the percentage of extender materials allowed in other sausage products. Those referred to as nonspecific (the word meat does not appear in the name), such as pickle and pimento, macaroni and cheese, and luxury loaves are not restricted in respect to their content of extender materials.

Soy Protein Extenders

Soy protein extenders are available as three main classes of products, namely, soy flour, soy protein concentrates, and soy protein isolates. Soy flour is available as full fat flour and as defatted flour, the former containing about 30% protein and 20% fat and the latter containing at least 50% protein. Generally, the term soy flour refers to the defatted flour only and is the only soy flour used in processed meats. Soy concentrates and isolates are prepared from soy flour or grits by removing the carbohydrates, which are responsible for the beany flavor and flatulence. This is accomplished by minimizing the solubilty of the proteins while washing out the carbohydrate material. Concentrates contain a minimum of 70% protein and isolates at least 90% protein.

Although soya flour is cheaper, concentrates and isolates have less beany flavor and contain less of the constituents causing flatulence. They are also higher in protein. All three products, however, are used in processed meats, with soy flour or grits being largely confined to sausages. Soy flour or grits are also widely used as meat extenders in fresh ground meat, as allowed by the school lunch program, and more recently by the United States Armed Forces.

Textured soy proteins are prepared from soy flours, concentrates, and isolates by thermoplastic extrusion under pressure. Thus, textured soy proteins differ in protein content and flavor, depending on the starting material utilized for their manufacture. The technology is also available for production of spun soy protein fibers. The fibers are made by solubilizing the soy protein in alkali and forcing the solution through a spinneret into an acid bath, which spins it into fibers. The fibers can be utilized to make meat analogs by adding flavoring materials, binders (usually egg albumen), and fat. Analogs made in this manner are fairly expensive and have not been widely accepted, except for a few isolated products such as imitation bacon bits.

The soy proteins are not only effective as protein extenders, but they also increase water and fat binding. The concentrates and isolates may also have some special gelling properties that aid in binding chunks of meat together in sectioned and formed meat products. The same products may increase fat emulsification in sausages, although some preparations may not be effective due to their insolubility at the pH of meat, i.e., pH 5.2–5.8.

Milk Protein-Derived Extenders

A number of milk protein derivatives are also widely used in processed meat. Those products utilized in processed meats include nonfat dry milk (NFDM), calcium-reduced nonfat dry milk, dried whey, whey protein concentrate, buttermilk solids, the caseinates, and skimmilk co-precipitates. The approximate composition of some of the available milk protein derivatives is given in Table 11.3.

NFDM is prepared by heating centrifugally separated skimmilk to pasteurize and concentrate it to 45–50% solids. It is then dried by either spray or roller drying. Although the former process is generally rated as producing higher quality NFDM, most MFDM used by the meat industry is produced by roller drying. NFDM is widely used in sausages because it increases water and fat binding and is cheaper than high quality meat proteins. There is also good evidence that it improves the texture and flavor of emulsion-type sausages, when used up to the legal limit of 3.5%. It is not only high in protein, containing about 36%, but is low in fat having only 0.8%. NFDM, however, has the disadvantage of being high in lactose and ash (Table 11.3), as are most other milk protein additives.

Calcium-reduced nonfat dry milk is produced by removal of 20–70%

TABLE 11.3. Approximate Composition of Some Milk Protein Derivatives Utilized in Processed Meats in United States

	Composition in %—Dry Basis				
Product	Protein	Moisture	Fat	Lactose	Ash
Nonfat Dry Milk (NFDM)	35.9	3.0	0.8	52.3	8.0
Calcium-reduced NFDM[a]	36–39	3.0	0.8	52.3	4–7
Dried Whey	12.0	4.5	1.1	73.5	8.0
Whey Protein Concentrates	20–60	2.0	2–9	18–60	3–18
Dried Buttermilk	34.4	2.8	5.3	50.0	7.6
Caseinates (Na^+, K^+, or Ca^{2+})	92.0	4.0	0.8	—	1.5
Skimmilk co-precipitates	83.0	4.0	1.5	1.0	10.0

Source: Hugunin and Ewing (1977)
[a]Estimated by authors

of the calcium from NFDM and substituting sodium. The addition of sodium results in a powder with a pH of 7.5, which is undesirable in meat products. The sodium is then replaced with hydrogen ion, which brings the pH back down to somewhere between 6.0 and 7.0. This process produces NFDM with solubility characteristics superior to ordinary NFDM, but otherwise having similar properties. The modification is reported to increase water and fat binding and to improve emulsification of fat. The cost, however, is somewhat higher.

Dried whey and modified whey products have recently been approved for use in several meat products. These whey derivatives are by-products of cheese and cottage cheese production. Since most of the casein is removed in the manufacture of cheese, the principal protein remaining in the whey is lactalbumen, which is also a high quality protein of excellent nutritional value. Although dried whey contains only 12% protein, some of the modified whey protein concentrates are much higher as well as being lower in ash and in lactose (Table 11.3). The modified whey products include whey protein concentrate, reduced lactose whey, and reduced minerals whey. They not only increase protein content but also serve as binders and thickeners in various sausages and other processed meats. Although their use is limited to 3½% in sausages including bratwurst, up to 8% can be used in chili con carne and pork and beef with barbeque sauce.

Dry whole milk, which is seldom if ever used in processed meats, and dry buttermilk are also produced by drying. Both have a composition similar to NFDM, except they have a higher content of fat. Dried buttermilk contains both casein and lactalbumen. It can be prepared from either sweet or sour cream. The sweet cream buttermilk has a milder flavor, whereas, sour cream or acid buttermilk has an acid or tangy flavor and is suited for use in fermented sausages. In actual marketing, dried buttermilk is often a mixture of the sweet and sour cream products. Dried buttermilk has the ability to emulsify fat as well as to function as a binder and thickening agent.

Caseinates are produced from pasteurized skimmilk either by treating with rennet, by direct acidification, or by culturing with lactic acid producing microorganisms, with the casein being precipitated at pH 4.3–4.5. The ash content is lower at this pH than that precipitated at higher pH values. The curd is easily separated from the whey fraction and is washed and dried. The casein curd is neutralized with either sodium, potassium, or calcium bases at pH 6.8–7.5 to produce their corresponding caseinates. The caseinates are good food ingredients and are widely used as protein extenders in processed meats. The sodium and potassium caseinates are generally used because they are more soluble than the calcium caseinate. They impart some water and fat binding properties to sausages but do not have fat emulsification properties at the normal pH of meat.

Skimmilk co-precipitates are produced by the co-precipitation of both the caseins and the whey proteins, mainly lactalbumen. The co-precipitation methods involved usually utilize heat and adjustment of the pH by acid, alone or in combination with hexametaphosphate, or addition of calcium chloride to precipitate most of the milk proteins. Co-precipitation produces a greater yield of proteins from milk, enhances the functional value of the proteins in other foods, and increases their contribution to nutrition. Co-precipitates also contain decreased lactose levels in comparison to other milk-derived protein extenders. The composition of the skimmilk co-precipitates varies, depending on the processes involved in their preparation. Thus, low-, intermediate-, and high-calcium co-precipitates are available and have been tested in meat products. Evidence suggests that all three calcium-modified co-precipitates can be used successfully in meat products. Their flavor appears to be acceptable in meat items, varying from sausages to ground beef. The skimmilk co-precipitates appear to not only provide high quality proteins and serve as protein extenders in processed meats, but also improve fat and water binding and act as thickening agents.

Yeast Protein-Derived Extenders

Although several yeast proteins are available and are added to a variety of processed meat items, they generally fall into two main classes: (1) dried yeasts, and (2) yeast extracts. The total solids, sodium chloride content, protein content, and their pH in a 10% solution is shown in Table 11.4. Some of the products and their usefulness in processed meat products is also briefly described.

Although higher in moisture and lower in protein than dried yeasts, the yeast extracts are more widely used in processed meats because of a more desirable flavor. Yeast extracts, however, are much higher in sodium chloride. Both dried yeasts and yeast extracts are by-products of the brewing industry and are not only excellent protein extenders but are also rich sources of the B-complex vitamins.

The yeast-derived additives are good protein extenders for meat products. They have a pH that suggests they may be good emulsifying agents. Most of these derivatives have a meaty flavor and would be expected to enhance the flavor of meat products. The yeast extracts have been widely used in various meat products.

Sausage Flours and Starch

A number of specially processed flours are prepared for use as extenders in some types of sausages as allowed under USDA regulations. These flours are made from cereal grains, such as corn, durum wheat, rice, and rye, and from potato starch. Although the flours are largely carbohydrate, they do not ferment unless enzymatically hydrolyzed.

The sausage flours are used as binders and as extenders because of their relatively low price in relationship to good quality meat proteins.

TABLE 11.4. Yeast Products Utilized in Processed Meats Showing Some of Their Characteristics and Uses

Products	Total solids (%)	Sodium chloride (%)	Protein (N × 6.25) (%)	pH of 10% solution	Uses in processed meats
Dried Yeast[a]	92–93	Negligible–5	45–52	5.6–5.8	Pizza, Ravioli, Sausage Rolls
Yeast extracts[b]	70–95	11.5–15.0	38–54	5.6	All types of meat products

[a] Dried autolized yeast combines the nutrients of dried yeast with an appetizing savoury flavor that gives products a meaty flavor.
[b] Gives a meaty flavor and is widely used in meat products.

They absorb large amounts of water and when water is added become sticky, causing the ground up meat particles to adhere to each other. The latter characteristics gives these flours and starch the descriptive name of binders.

Mustard flour functions both as a condiment and as an additive. It is ground and used either as the unrehydrated flour or as heat-treated flour. Heating inactivates the enzyme that breaks down the natural glucosides in the mustard seed, so heat-treated ground mustard contains less of the isothiocyanate compounds that are responsible for the sharp flavor. The amount of mustard flour is limited by the sharpness of the flavor when mixed with meat products. Levels used vary from 4 oz up to 1 lb per 100 lb of meat and are determined by both the flavor of the flour added and by the type of sausage to which it is added.

Mustard flour contains natural mucilagenous materials that improve the peelability of sausages and proteins that absorb the free gelatin, preventing jelly pockets. It also has antioxidant properties.

OTHER ADDITIVES

Antioxidants

Ground mustard seed has already been discussed as imparting antioxidant activity to sausages. Sodium chloride coated with antioxidants has also been shown to be effective in retarding rancidity in meat products.

A number of commercial antioxidants are available on the market. Their usage and allowable levels are controlled by USDA regulations. They can be divided into two main groups based on their solubility properties, i.e., (1) fat soluble, and (2) water soluble. The fat-soluble antioxidants include butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), catechin, quercetin, and 2, 6-dimethoxyphenol (DMP). The water-soluble antioxidants include ascorbic acid, citric acid, phosphoric acid, and nitrite. The antioxidants are frequently mixed together because of their complimentary affects in preventing oxidation.

Flavor Enhancers

Monosodium glutamate (MSG), inosine monophosphate (IMP), and guanosine monophosphate (GMP) are used as meat flavor enhancers as allowed under USDA regulations. They are most often used in meat loaves, soups, stews, hash, and in canned and deviled ham. There seems to be little advantage to using these flavor enhancers in products containing a high proportion of meat protein, but they can improve flavor where the amount of high quality meat protein is limited.

Condiments, such as pistachio nuts, may be used in some sausages such as head cheese and scrapple. They provide a distinctive flavor and enhance the attractiveness of these products, but their high cost is virtually eliminating them from use in meat products.

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12

Cured and/or Smoked Meats

Meat products that are cured are frequently, but not always, smoked. Although these cured products are often called smoked meats, more correctly, products in this class should be called cured and/or smoked meats, since all of them are cured while only some of them are smoked and/or cooked.

The principal cured and smoked meat products are made from the primal cuts of pork and consist mainly of ham and bacon. It is a common practice in the meat industry to separate production and marketing of these products. Meat processing companies often have smoked meat departments, which produce and market hams, picnics, and other smoked meat products, and bacon departments that mainly produce sliced bacon. Thus, management responsibility for bacon production and sales is generally separated from smoked meats production and marketing.

Years ago most smoked products were not cooked. Now most smoked meat products are cooked, usually during or immediately following smoking. Smokehouses today would more correctly be called cookhouses or ovens since less smoking and more cooking is being done. There are exceptions, however, probably the most notable being Country hams, which are smoked but not cooked. Corned beef and cooked hams are cured meats that are not smoked. Smoked fresh beef, pork, and lamb that are used for banquets or barbecuing are smoked but not cured. Although cured and/or smoked meats are commonly thought of as being pork products, cured, smoked beef and, to a lesser extent, lamb products are also produced.

Table 12.1 lists most of the cured and/or smoked meat products and shows whether or not they are cured, smoked, and cooked. The processing differences are evident, although most of the products are cured, smoked, and cooked. Bacon and hams comprise the majority of these products in terms of volume.

HAMS

Classification of Ham

Federal meat inspection regulations form a basis for differentiating hams in two ways: (1) according to the highest internal temperature

A. M. Pearson et al., *Processed Meats*

TABLE 12.1. Processing Procedures

Product	Cured	Smoked	Cooked
Bacon	yes	yes	partially[a]
Canadian bacon	yes	yes	yes[b]
Jowl bacon	yes	yes	partially
Breakfast bacon	yes	yes	partially
Fat-back	yes	no	no[c]
Smoked ham	yes	yes	yes
Fully cooked ham	yes	yes	yes
Country ham	yes	yes	no
Smithfield ham	yes	yes	no
Scotch ham	yes	no	no
Prosciutto	yes	yes	no
Cooked ham	yes	no	yes
Baked ham	yes	yes/no	yes
Picnic	yes	yes	yes
Shoulder butt	yes	yes	yes
Smoked pork loin	yes	yes	yes
Corned beef	yes	no	yes/no
Dried beef	yes	yes/no	no
Smoked tongue	yes	yes	yes
Pickled pigs feet	yes	no	yes
Smoked lamb	yes	yes	yes
Smoked fresh meat	no	yes	yes

[a] Partially: more than 100°F but less than 140°F
[b] Yes: 140°F internal temperature or above
[c] No: less than 100°F internal temperature

they reach during cooking, and (2) according to the amount of added substance they retain after processing. In effect, these regulations control product recognition and labeling and, in so doing, form the basis for a system of classification. Presence or absence of bone is a third method of classification.

Internal Temperature. Federal inspection regulations recognize two classes based on the internal temperature that hams achieve in the smokehouse: smoked (140°–147°F), and fully cooked or ready-to-eat (148°F and above). The terms cooked, thoroughly cooked, fully cooked, ready-to-serve, and ready-to-eat are synonymous. To ensure destruction of trichina, the microscopic parasite responsible for trichinosis, Federal inspection regulations specify that hams must reach an internal temperature of at least 137°F. Country hams are not cooked, but are rendered safe to eat by being subjected to a prolonged curing process. Country hams are usually cooked before being eaten. Hams classified by the Federal government as smoked should also be cooked further before being eaten. To increase palatability, these hams are generally cooked to internal temperatures above 160°F by consumers. Moreover, fully cooked hams, which are required to reach at least 148°F, are generally cooked by meat processors to at least 152°F to increase palatability without additional cooking by consumers.

Prior to incorporation of nitrite in the cure and introduction of the arterial pumping technique, the internal temperature of hams cooked in smokehouses seldom exceeded 137°–140°F. With these two technological innovations, hams were cured faster. They tended to be more mildly flavored, and it became a fairly common practice for ham processors to exceed 137°F internal temperature in the smokehouse. Such hams became commonly known as tendered. In time, processors produced even more moist and more mildly cured, as well as more tender, hams. To accomplish this, hams were pumped with additional pickle, placed directly in the smokehouse and subjected to even higher temperatures, but less smoke. From this series of changes emerged the so-called ready-to-eat or fully cooked hams. Today, the trend is toward increased production of fully cooked hams.

Added Substance. Most hams today are cured by pumping with solutions in which the cure ingredients are dissolved in water. For this reason Federal meat inspection regulations recognize three ham categories depending on the amount of added substance remaining in hams after processing. Added substance refers to water and salt present in the cured product in excess of the normal amount occurring in the uncured product. Labeling restrictions are shown in Table 12.2. A proposal to label cured hams on the protein-fat-free (PFF) basis for added water has recently been adopted and will become effective in 1985. The exact implications are not fully understood, but will supersede the labeling restrictions shown in Table 12.2.

Basically, government control is expressed in terms of weight, that is, the weight of the finished product cannot exceed its fresh, uncured weight unless labeled appropriately. In actuality, control is exercised through calculation based on chemical analysis. There are inevitable differences between actual and calculated yields, but inspection procedures recognize these variances with a scale of tolerance. Tolerances are expressed in the form of statistically validated ranges based on the number of samples analyzed. Control by chemical analysis is based on calculation according to the following formula:

$$\text{estimated yield} = \%\ \text{moisture} + \%\ \text{salt} - k \times \%\ \text{protein} + 100$$

TABLE 12.2. Ham Labeling According to Added Substance

Federal labeling restriction	Added substance in finished ham
No labeling restrictions	None
Labeled "Water Added"	Up to 10%
Labeled "Imitation"	Over 10%

TABLE 12.3. Protein Multipliers

Product	*k* Factor
Smoked picnics, butts, and miscellaneous products	4.00
Canned picnics	3.93
Canned hams and other canned pork products	3.83
Smoked hams	3.79

The protein multiplier or *k* factor is an average figure representing the approximate ratio of moisture to protein. The *k* factor differs among products. Factors recognized by federal inspection authorities are shown in Table 12.3.

Presence of Bone. Except for some long-cut hams, which may contain part of the backbone, whole intact hams contain three bones—(1) aitch, (2) body, and (3) shank. The presence or absence of one or more of these bones in a processed ham forms the basis for still another method of grouping hams, as shown in Table 12.4.

Whole bone-in hams are comprised of three segments—(1)butt, (2) center, and (3)shank. Bone-in hams can be sold whole or cut into sections. When cut in half, the sections are referred to as a butt half or shank half. If one or more center slices are removed after hams are cut in half, the remaining butt and shank sections are called portions, either butt or shank. Once the center slices are removed, they are no longer half hams.

Semi-boneless hams are designed to provide convenience to the consumer while retaining some of the appeal of the bone-in product. Aitch and shank bones are removed. This leaves only the femur or body bone, which facilitates carving by the consumer. A few semi-boneless hams are produced in which only the aitch bone has been removed, leaving the body and shank bones intact.

The anatomical structure of hams lends to division into two or three primary sections. Preparation of these sections is discussed in detail in Chapter 7. Generally, heavier hams weighing 18 lb and up are used for preparation of sectioned ham products.

With increased emphasis on consumer convenience, boneless hams have grown in popularity during recent years. They are manufactured in either round or flat shapes. Round boneless hams are made in cellulosic casings. In the last few years, the fastest growing segment of the boneless ham market has been flat hams, produced by pressing boneless hams between wire screens. Prior to pressing, hams are stuffed into either stockinettes or cellulosic casings. The hams are then fully cooked in a smokehouse. Because they are cooked, the flat shape is retained when the screens are removed.

One of the most recent developments in the production of boneless

TABLE 12.4. Ham Classification According to Presence of Bones

	Bone		
Type	Aitch	Body	Shank
Bone-in	Present	Present	Present
Semi-boneless	Absent	Present	Absent[a]
Boneless	Absent	Absent	Absent

[a]A limited number of semi-boneless hams are produced with both body and shank bones left intact.

hams is binding of ham chunks by tumbling to extract salt soluble protein, compressing the small sections in metal molds, and cooking. The end result is a solid piece of meat produced from smaller pieces. This patented process is used to manufacture chunked-and-formed ham slices.

Commercial Ham Manufacture

Curing. Whether classified as smoked or fully cooked, whether bone-in or boneless, whether flat or round in shape, most commercially produced hams are cured in a similar manner. Since the middle 1930s most have been pickle-cured. A typical curing pickle consists of salt, sugar, sodium nitrite, and phosphate. In addition, corn syrup and sodium erythorbate are used frequently. Government regulations restrict amounts of corn syrup, nitrate, nitrite, phosphate, and erythorbate that can be used. Restrictions, based on a 10% pump level, are as follows:

Corn syrup: Corn syrup may not exceed 60 lb per 100 gal pickle; corn syrup solids are limited to 50 lb per 100 gal.
Phosphate: Finished products may not contain more than 0.5% of an approved phosphate.
Erythorbate: Pickles may not contain in excess of 87.5 oz per 100 gal pickle.
Nitrite: Pickles may not contain in excess of 2 lb per 100 gal and finished products may not contain more than 200 ppm.

An example of a curing formula is given below. See also chapter 7.

Pickle Formula

Ingredients	*lb*	*oz*
Water	70	
Salt	20	
Sugar	6	11
Sodium tripolyphosphate	2	14
Sodium ascorbate		4
Sodium nitrite		2.5

Pumping with a 10% pump will give 2% salt, 150 ppm of sodium nitrite, and 250 ppm of sodium ascorbate in the pumped product. The salometer strength of this pickle is about 65°, depending on pickle temperature. This formulation can be used for hams pumped to 110% of green weight. For hams pumped in excess of this, modifications are required; otherwise, the hams (1) are too salty, and (2) do not conform with Federal regulations relating to ingredients. For example, hams pumped to 120% require reducing all ingredients by 50%, except water. Commercial processors generally prepare 100° stock pickles and dilute with water to the strength pickle they wish to pump. Because of their low solubility in brine, phosphates are dissolved in water and then combined with the pickle. Erythorbate is best added with a minimum of agitation shortly before the pickle is to be used.

Because injection machines allow for increased automation, their use is gaining in popularity. Curing pickle is injected directly into the ham musculature by a multiple-stitch needle machine, or through an artery-injection needle into the arterial system from where it diffuses into the muscle tissue. Either method allows curing ingredients to diffuse throughout hams much faster than is possible by dry rubbing or immersion in pickle. Curing pickle was first injected into ham muscles through individual-stitch needle injections. The injection process was improved upon when it was learned that curing pickle could be introduced via the arterial system. Many packers still use the arterial pumping system for curing hams, but many others now use multiple-needle injection machines. When needles are attached to the machine with a flexible coupling, bone-in products can be injected.

The amount of cure injected into hams depends on (1) the type of ham being cured, that is, whether regular, water-added, or imitation, and (2) the amount of moisture lost by the hams during processing. Processing loss includes pickle released by hams shortly after pumping, smokehouse shrink, and cooler shrink.

After hams are pumped, they are either placed directly in the smokehouse or held in a cooler for up to 24 hr. To achieve maximum quality, hams are placed in cover pickle for 3 to 7 days. Hams cured in cover pickle have better color development, better color stability, fewer uncured spots, more uniform distribution of salt, better flavor, and improved water-binding.

Smoking/Cooking. The next step in manufacture is to smoke and cook hams in the smokehouse. A typical cook schedule starts at 130°–140°F. After 2 hr, the temperature is raised to 150°–160°F, and then after an additional 2 hr it is further increased to 170°–180°F. If smokehouses have provisions for controlling relative humidity, hams should be cooked in an atmosphere of 30–40% relative humidity. Although graduated schedules are still in common usage, more processors are turning to single-temperature schedules. Such schedules call for starting and maintaining one temperature, generally 170°–180°F, from beginning to end of the cook schedule. The length of time hams remain in the smokehouse depends on (1) size of ham, (2) the final internal temperature desired, (3) air velocity in the smokehouse, and (4) the cook schedule employed. Hams are generally subjected to a natural wood smoke.

Cooked Ham

Cooked hams are sometimes referred to as boiled hams. However, the term "boiled ham" is a misnomer. Federal inspection regulations forbid labeling hams as boiled unless they are actually cooked in boiling water. Cooked hams are boned and stuffed into metal molds. They are not boiled but are cooked in tanks in 165°–180°F water to internal temperatures of 152°–160°F. These hams are seldom subjected to smoke and are invariably sold sliced for sandwiches.

A recent innovation in cooked hams has been the development of plastic containers, which are made from forming and non-forming films. This procedure has been called "cook-in hams," although the process of cooking is the same as for those in metal cans. More details on this procedure is given in Chapter 13.

Baked Ham

Federal regulations specify the termed "baked" shall apply only to products that have been cooked by direct action of dry heat for sufficient time to permit them to assume the characteristics of baked items. Baked hams must reach an internal temperature of at least 170°F. To avoid the great expense associated with manufacture of baked hams, processors produce baked-style hams. These are usually prepared from conventional cooked hams. Chilled cooked hams are dipped in a gelatin-based glaze. Frequently the top surface of these hams is decorated with pineapple slices and maraschino cherries.

Baked-Style Ham Glaze

Ingredients	*lb*	*oz*
Corn syrup	5	
Brown sugar	2	
Finely ground paprika		6
Soluble clove		4
Gelatin	2	
Water	4	2
Pineapple juice	4	5

Preparation. Disperse the gelatin in cold water and heat. Incorporate all other ingredients. When the mixture has cooled to 120°F, immerse the hams. Remove immediately and let chill. Decorate the surface before the gelatin solidifies.

Country Ham

The only uncooked hams produced in the United States of any commercial significance are Country hams. "Country" or "Country style," when applied to hams and shoulders, is a generic term which indicates characteristics and not the location of manufacture.

Federal regulations require products that are not actually produced in the country to be labeled Country style. Country and Country-style hams and shoulders must be free of trichinae, be dry-cured, have a salt content of at least 4%, and shrink a minimum of 18% during processing.

The appearance and most certainly the flavor of Country hams differ dramatically from common pickle-cured hams. The salty, somewhat dry, rather hard, highly flavored product known as a Country ham is produced primarily in southern regions of the United States. Its history dates back to colonial times. The colonists developed a method of curing hams so they would be preserved through the hot summers. This tradition has continued ever since.

The first Country hams came from hogs grown in the peanut belt in Virginia and North Carolina. The best known Country hams are Smithfield hams produced in Smithfield, Virginia. In 1925, the Virginia State Legislature passed an Act stating that hams must be processed in the town of Smithfield to be called Smithfield hams. While processors in a number of southern states use essentially the same curing method as that used for Smithfield hams, connoisseurs disagree as to which Country hams are best—those produced in Virginia, North Carolina, Tennessee, Kentucky, Georgia, or Missouri.

Preparation. A good mixture for curing Country hams is a combination of 8 lb salt, 1 lb sugar, 2 oz sodium nitrate, and 1 oz sodium nitrite per 100 lb of carefully trimmed hams. This is equal to 1½ oz of cure per pound of ham. The curing mixture should be divided into three equal portions. Apply one-third of the cure immediately, the second portion 7 days later, and the remainder on the fourteenth day. Thoroughly rub the mixture into the meat with each application, being certain to get adequate amounts of the cure around the bones on both the shank and butt ends. Some of the cure should be forced around the aitch bone, which can be accomplished by using the index finger to make a hole. This will aid in preventing spoilage, which most frequently begins around the large bones.

Curing should be carried out under refrigeration at a temperature of 36°–40°F and a relative humidity from 70 to 90%. The curing time will require 30–40 days depending on the size of the ham. The cure penetrates primarily through the fleshy surfaces and not through the skin side of the ham, the time required depends on their thickness and weight for which times are shown in Table 12.5.

In large commercial operations, hams are cured in stacks. Layer after layer of hams is put down. A mixture of salt, sodium nitrate, and often sugar is shoveled on the hams. Then another layer of hams is placed on top of the preceding layer, and so on until the ham stacks reach about 4 ft in height. The hams are then left to cure. Hams are generally over-hauled two to three times during the curing period.

The nitrate in the cure is gradually reduced to nitrite, and thus provides better color development and flavor than nitrite alone, since it becomes available more slowly. The cure does not penetrate the deep tissues during the early phases of curing. Thus, the nitrite derived from reduction of nitrate is available later when it is needed in the interior of the ham.

Some commercial producers use only two applications of cure, with the first half being applied immediately and the remainder 14–16 days later. Regardless, the hams need to be cured for 30 to 40 days, depending on their size.

The hams should then be held for an additional 20 day period to allow for salt equalization. Holding should be at a temperature of 36°–40°F and at a relative humidity of 75–90%. The same room used for curing is often used for salt equalization. The salt content of the product decreases in the surface layer and increases in the deep tissues during this process. Figure 12.1 illustrates the changes occurring in salt content during salt equalization by contrasting it with that at the end of curing. As shown, the salt content becomes more uniform throughout. This is important not only from the standpoint of flavor but also for preservation.

Aging of country hams is carried out following salt equalization. They may be hung by the shank and using a cotton string, or else placed in stockinette and suspended from a rack. The aging room should be held at a temperature of 70°–95°F and a relative humidity of

TABLE 12.5. Average Curing Time for Country Hams According to Weight and Thickness

Weight of hams[a]	Approximate thickness[b]	Approximate curing time[c]
14–16 lb	4–5 in.	28–35 days
18–20 lb	5–6 in.	35–42 days
22–24 lb	6–7 in.	42–49 days

[a] Trimmed green weight into cure.
[b] Thickness from face of ham to back of ham skin.
[c] Curing temperature at 36°–40°F.

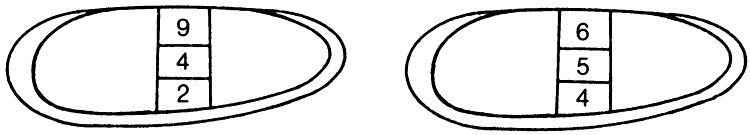

FIG. 12-1. Diagram showing the distribution of salt at the end of curing and again following a 20-day salt equalization period.

50–60%. The hams should be kept in the aging room for minimum of 6 months. This results not only in a reduction in moisture content and an increase in salt content, but also in an improvement in flavor.

Because Country hams tend to become progressively harder and their flavor accentuated as aging continues, they should not be aged for more than 9 to 12 months. Although higher temperatures can be used and will speed up aging, the resulting flavor is not typical of country hams.

If Country hams are to be smoked, it should be done after aging. The hams should be given a cool smoke at a temperature of 70°–90°F. The internal temperature of the hams will be about 10°F lower than the smokehouse temperature. Smoking should continue for 1½–2 days or until the hams become amber or mahogany in color.

Country hams have a final moisture content of 50–60% and an average salt content between 4½ and 5½%. The high salt and low moisture content allows storage without refrigeration. Shrinkage during processing amounts to 7–8% during curing and salt equalization, while an additional 12–15% is lost during aging.

Two major problems occur during production of Country hams: (1) spoilage due to problems in curing, especially as a result of improper temperature control, and (2) mold growth during salt equalization and aging. The spoilage problem can be greatly decreased by being sure that the temperature during curing and salt equalization is held in the range of 36°–40°F. Temperatures lower than 36°F delay salt penetration and require longer times for both curing and salt equalization, whereas, temperatures above 40°F result in a greater incidence of spontaneous spoilage. Taking care to force the cure around the bones of the shank and butt and around the aitch bone during rubbing will also aid in reducing spoilage.

The best way to control mold growth is careful maintenance of the humidity gradient so that surface drying occurs throughout the process of aging. Mold can be wiped from the surface of Country hams using a cloth dampened with edible oil. The process, however, is labor intensive, and thus expensive.

The lean of Country cured hams is dark red and very firm, while the fat is quite yellow. Flavor is intense and distinctive. Most Country hams are rubbed with finely ground black pepper. Some processors rub their hams prior to smoking while others do not apply pepper until the hams are aged and ready for sale.

In addition to Country hams, three other uncooked hams are sold in the United States, principally to meet the demands of limited ethnic markets. These hams are Westphalian, Scotch, and prosciutto.

Westphalian Ham

Westphalian hams are produced in Germany. These uncooked hams have a distinctive flavor produced by smoking with juniper twigs and berries spread over a beechwood fire. Westphalian hams are sliced thin and eaten uncooked.

Preparation. Hams with the aitch bone and shank removed are rubbed with a mixture consisting of 16 lb salt and 2 oz sodium or potassium nitrate. This amount of curing mix is sufficient to cure 100 lb of green ham. They are then placed on shelves or stacked on concrete floors and allowed to cure for 10 to 14 days, after which they are placed in a 90° pickle and cured for an additional 2 weeks. They are then removed from the brine and stacked layer upon layer in a cool, dry basement where they ripen for approximately 1 month. Hams are then soaked in water for about 12 hr in preparation for the smokehouse. They are hung in the smokehouse for about 7 days and exposed to cool smoke generated from beechwood logs. From time to time, juniper twigs and berries are thrown on the smoldering fire.

Scotch Ham

Scotch hams are cured but neither smoked nor cooked. Fresh hams are skinned and most of the fat removed. The hams are then dry cured similar to dry-cured hams manufactured in the United States. The cured hams are boned and either rolled and tied or stuffed into casings. Similar hams produced in the United States must be termed Scotch style.

Prosciutto

These dry-cured Italian hams are somewhat similar to Country hams. The long curing and drying process results in about a 35% shrink in weight. The following curing formula will cure approximately 100 lb of green ham:

Pickle Formula for Prosciutti

Ingredients	*lb*	*oz*
Salt	3.5	
Cane sugar	1	4
Dextrose	1	4
Allspice		8
White pepper		5
Black pepper		2
Nutmeg		2
Mustard seed		0.5
Coriander		0.5
Sodium nitrate		0.5
Sodium nitrite		0.25

Preparation. Select good-quality fresh hams weighing from 12 to 18 lb. Since prosciutti hams are customarily eaten without being cooked, they must be produced from hams that have been certified to be free of trichina. The foot should be cut off below the hock so the shank is left extra long. The aitch bone is removed to allow the ham to be flattened. The hams are placed on platforms approximately 12 in. off the floor. The platforms should be in a dry cooler at approximately 36°–38°F. Hams should be rubbed thoroughly with the curing mixture. They are then piled four high on the platform with the skin side down, and some of the curing mixture is sprinkled over the top of each layer. The pile is overhauled in 10 days and the hams on top are placed on the bottom. Each ham is rerubbed with the curing mixture. The hams are then overhauled a second time in another 12 days. The hams should be left in cure for a total of approximately 45 days. Hams handled in this manner will come out flat and dry. However, if after the curing period still flatter hams are desired, they can be laid on planks and then planks and additional weight placed on top of them. A ham thickness of about 2 in. is considered desirable for prosciutti hams. Some processors place the hams in pressure molds during the cure to ensure that they reach the desired flatness. After the hams come out of cure, they are soaked in 80°–90°F water to soften the skin, and scrubbed with soft-fiber brush so they will not show salt streaks when they come out of the smokehouse. Next, the hams are strung with twine. The twine is not forced through the meat; instead, a double loop is made, the shank encircled, and the knot tied. The hams are then placed in a smokehouse at 130°F and allowed to remain there for 48 hr. The temperature is raised gradually to 140°F and kept there for about 2 hr. Then the temperature is dropped to 120°F for 8 hr. From 120°F, the temperature is gradually reduced so that when the hams are ready to come out of the smokehouse, the house temperature should be 95°–105°F. To ensure firmness, the hams should be hung outside of the smokehouse to cool for approximately 8 hr. Finally, the hams are rubbed on the meat side with a mixture of equal parts of white and black pepper. This should be done carefully to avoid getting any pepper on the skin. The meat side of the hams should look almost black when the rubbing has been completed. The hams are then aged for 30 days at a temperature of 70°–75°F and a relative humidity of 65–75%. Prosciutti hams manufactured in a packinghouse in this manner are very similar to those which have been made for centuries in Italian homes. Italians eat the ham cold but Americans frequently fry or warm it.

BACON

Since there are no quality grades for bacon, it does not readily lend itself to classification. Processors usually grade bacon in-plant on the basis of weights of the green bellies used in manufacture. These grades are strictly individual processor grades and are translated to the consuming public only in terms of brand names and prices. Generally, the heavier the bellies used for curing, the fatter, less tender, and darker color the bacon.

One of two methods is used to cure bacon: (1) dry cure or (2) pickle cure. In the case of dry-cured bacon, a mixture of curing ingredients is rubbed on all surfaces of the green bellies. Bellies are placed in a cooler to cure for 10 to 14 days before cooking and smoking.

Most commercially processed bacon today is pickle-cured. Pickle is introduced by a needle injection machine similar to that used for hams and other smoked meats. Rinds are removed from bellies destined to be sliced in-plant before being stitched. After pickle is injected, the belly is combed (pierced with a multipoint hanger) and hung in a smokehouse. The length of time bacon remains in the smokehouse depends on (1) size of the belly, (2) smokehouse air velocity, (3) cook schedule temperatures, and (4) internal temperature desired. Bacon is usually cooked in the smokehouse according to a three-step cook schedule. First, smokehouse temperatures usually range between 115° and 125°F. Dampers are open and the bacon is dried. Drying may last for 1 to 2 hr. During the second phase, lasting approximately 2 hr, dampers are closed and the temperature increased 5°–10°F. Dampers remain closed during the third phase, and the temperature is increased an additional 5°–10°F to as high as 140°F, or, as is the case with some processors, temperature is adjusted to 128°–130°F. Whichever the case may be, this temperature is maintained until the internal temperature desired is achieved, usually 126°–132°F. Today, it is common to find bacon processors cooking with a one-temperature schedule—generally 130° to 140°F. Cooking bacon to higher internal temperatures helps develop and stabilize the cured meat color. When air-conditioned smokehouses are used to cook bacon, relative humidity is maintained between 25 and 40%. Bacon is subjected to smoke during all or part of the cooking period depending on the requirements of individual processors.

After bacon is cooked and smoked, it is chilled and the rind removed, if it had not been done before being cured. Prior to slicing, bacon slabs are held in tempering coolers where internal temperature of the bacon is reduced to 26°–28°F. This is done to (1) allow bacon to retain its shape when it is subsequently pressed, and (2) to facilitate slicing. Chilled bacon slabs are then pressed or blocked. The pressing operation consists of placing slabs in a large forming machine which compresses the bacon to a relatively uniform whidth and thickness. Before pressing, bellies lack dimensional uniformity to such an extent that slicing yields suffer greatly. After being pressed, bacon slabs are sliced on high-speed slicers which automatically shingle slices into selected weight units. Bacon slabs are sliced to three different thicknesses: (1) thin, (2) regular, and (3) thick. Thin sliced bacon, sometimes referred to as hotel or restaurant sliced, is sliced approximately 1/32, regular is 1/16, and thick about 1/8 in. thick. The shingled bacon is either vacuum or nonvacuum packed. Vacuum packaging gives a longer shelf-life.

Canadian Bacon

Canadian bacon differs markedly from bacon manufactured from bellies because it is produced from the large muscle of pork loins, the strip or sirloin muscle. Very little intermuscular fat is encountered and most of the external fat is trimmed off, resulting in a characteristic finished product that is quite lean.

Boneless loins are stitch-pumped and placed in cover pickle for 2 to 5 days. After being removed from cover pickle, loins are washed with cold water, stuffed into cellulosic casings or stockinettes, and hung in a smokehouse, where the loins are smoked and cooked to an internal temperature between 150° and 155°F. Smokehouse schedules for Canadian bacon are similar to those for cooking hams. Either graduated or single-temperature schedules can be used. If relative humidity is controlled during cooking, it is generally maintained between 25 and 40%. Canadian bacon is sold either sliced or in chunk form.

Wiltshire Bacon

In much of Europe, and Great Britain in particular, bacon generally refers to a Wiltshire side. Wiltshire sides are made from selected hogs weighing between 150 and 200 lb live weight. The most desirable sides weigh 50 to 60 lb and have a backfat thickness of 1¼ to 1½ in. The shoulder, loin, belly, and ham are left as 1 piece. The foreleg is removed at the knee and the hind leg at the hock. The tenderloin, ribs, neck bone, back bone, aitch bone, skirt, and loose fat are also removed. Hind legs are sometimes removed from Wiltshire sides and sold separately. These are referred to as gammons. Shoulders, known as fore ends, are also frequently sold as separate cuts, but the remainder of the side is normally sliced for sale. Wiltshire sides are cured by pumping and are then placed in cover pickle, in which they generally remain for 7 to 10 days. They are then removed from the pickle and stored under refrigeration for from 2 days to 2 weeks. This is sometimes referred to as a maturation period. Following maturation, the sides may be smoked or sold without further processing.

Beef Bacon

Beef bacon, usually referred to as breakfast bacon, is made from boneless beef short plates. The short plates are cured and processed similar to pork bellies. Beef bacon is much less widely marketed than is bacon made from pork bellies or Canadian bacon.

Jowl Bacon

Fresh, trimmed jowls, sometimes called bean pork, are squared and subjected to the same curing, cooking, and smoking procedures as is bacon made from bellies. The resultant product is known as jowl bacon, or bacon squares. Jowl bacon is generally fatter than bacon made from bellies.

Fat Backs and Heavy Bellies

Fat backs, the heavy layer of fat removed from pork loins, and heavy bellies, weighing at least 20 lb, are cured by either the pickle or dry salt cure method. This product is commonly referred to as salt pork. When the dry-cure procedure is used, the pork is rubbed with salt and stacked 3–4 ft high in coolers. The meat is overhauled after 8 to 10 days, rubbed again, and restacked. Heavier cuts are overhauled once again about the twentieth day. Total curing time depends on thickness of the cut, but generally is from 20 to 30 days. Some processors add nitrate or nitrite to the cure; others use salt alone. Products that are pickle-cured are usually stitch-pumped and immersed in 90° salometer pickle. Such pickles may, but do not necessarily, contain nitrate or nitrite. As a rule of thumb, bellies, both dry- and pickle-cured, remain in cure 1 day for each pound of belly weight.

SMOKED PORK LOIN

Pork loins can be dry-cured but are usually pickle-cured. Commercially prepared, smoked pork loins are stitch-pumped with a pickle similar to that used to cure other pork primals. Stitched loins are then placed in cover pickle for 3 to 5 days. After curing, loins are smoked and cooked to 142°–152°F. Pork chops cut from smoked pork loins are sometimes referred to as Windsor chops.

PICNIC

Picnics are cured, smoked, and cooked in a manner similar to hams. They may be artery-pumped, but in most cases are stitched with an injection-needle machine. Picnics are subject to the same Federal inspection regulations with regard to added moisture and internal temperature that apply to hams. Because of their greater proportion of bone, fat, and connective tissue and lack of one or more large muscles, picnics are of less economic value than hams, so are marketed more competitively.

SHOULDER BUTT

Pork shoulder butts or Boston butts, as they are commonly known, are usually boned and trimmed, cured, smoked, and cooked in a manner similar to picnics and hams. Butts are manufactured according to the same Federal regulations that apply to hams and picnics. They may be placed in pickle in a curing vat for 7 to 10 days, but more frequently are stitch-pumped with curing pickle. After removal from the pickle, butts are stuffed into stockinettes or cellulosic casings, hung in smokehouses, and cooked to an internal temperature between 142° and 152°F. They are generally sold as cured and smoked pork shoulder butts. In the New England area, they are referred to as cottage rolls. For those who prefer a somewhat leaner bacon than is generally produced from bellies, butts may be sliced and fried as bacon.

CORNED BEEF

Corning refers to the preservation of beef by the use of salt. The word corn comes from the Latin *corne,* meaning a horn or a hardened and thickened portion of cuticle. The word corn was equivalent to grain, and in Britain, generally meant any small hard particle. The term "corned" thus came to apply to meat preserved by sprinkling with grains or corns of salt. Large amounts of corned beef are sold in the United States today. Some is taken from pickling barrels and refrigerators of small independent butcher shops. However, the largest portion is prepacked and sold in supermarkets. A consumer desire for leaner meat products has led some processors to prepare corned beef from muscles of the round instead of the traditional brisket. Regardless of which cuts are used, the basic corning process is the same. The principal means of curing corned beef is to inject pickle into the beef. Previously, beef cuts were placed into pickle in curing crocks and cured for varying periods of time, depending on the thickness of the cut.

The basic curing pickle used to produce corned beef does not differ from that used to cure hams or other smoked meats. However, it is not unusual to include in corned beef pickle an assortment of spices and herbs, such as laurel leaf, allspice, or garlic. On occasion, celery and onions are also used.

Federal regulations permit briskets to be pumped to 120% of green weight, but other cuts, such as sections of the round, may only be pumped to 110%. The meat is then placed in cover pickle for a few days. For beef corned by simply immersing in pickle, approximately 2 weeks in pickle is necessary for cuts 3 in. or less in thickness. If corned beef is to be sold ready-to-eat, it is cooked in water or steamed to an internal temperature of 152°–160°F.

Cooked corned beef is usually red, but there is a particular type produced in the New England region which is gray-brown in color, as a result of omitting nitrite from the curing formula.

Corned beef briskets can be purchased either uncooked or cooked and sliced. The chunk of beef is removed from the bag and simmered until tender. It is often served with boiled cabbage and other vegetables.

SMOKED FRESH MEAT

Smoked fresh meats are not commercially significant, probably because the short shelf-life associated with fresh meat products. However, caterers serving large groups occasionally offer fresh, smoked beef or pork in sandwiches. Cuts selected are usually high-quality beef rounds and loins and pork hams and loins. The meat may be completely cooked in the smokehouse as it is being smoked or subjected only to cold smoke. When meat is cold-smoked, the temperature of the smokehouse does not exceed 100°F. Smoking is continued until the desired amount of smoke is deposited on the product. Meat that has been cold-smoked is then cooked in a conventional oven before serving.

DRIED BEEF

Dried beef is cured, dried, and sometimes smoked, but not cooked. Moisture content is low, usually 25–35%. Either the dry- or pickle-cure procedure can be used, although most commercially produced dried beef is cured in pickle. A typical curing formula follows:

Pickle Formula for Dried Beef

Ingredients	*lb*	*oz*
Salt	6	
Sugar	3	
Nitrate		2.75
Nitrite		0.25

Procedure. If the meat is dry-cured, 1 oz per pound of meat of the curing mix is applied to the meat surface. The curing mix should be applied in two rubbings at 5-day intervals. If the pickle cure is used, the cure ingredients are dissolved in 4 gal water. This provides sufficient pickle to cover approximately 100 lb meat.

The length of time the meat remains in cure depends on the size of cuts being cured. Generally, muscles of the round–top, bottom, and knuckle–are used for manufacture of dried beef, but shoulder clods are also used. As a rule of thumb, dry- or pickle-cured meat should remain in cure a minimum of 2 and a maximum of 3 days per pound. After being removed from cure, the meat is rinsed with cold water and allowed to dry. When produced in a commercial establishment, the beef is generally dried in a smokehouse for 2 to 3 days. Smokehouse temperatures range between 90° and 100°F. Depending on the desires of individual processors, smoke is applied during part of the drying period.

SMOKED AND CURED LAMB

Both lamb and mutton legs and shoulders lend themselves to curing and smoking. However, these products are of no commercial significance in the United States. Curing formulations and procedures, as well as cooking and smoking schedules, are similar to those used for curing primal pork products.

SMOKED TONGUE

Although beef tongues are generally used, pork, sheep, and calf tongues are also smoked on occasion. They are stitch- or artery-pumped. Curing pickles and cooking and smoking schedules are similar to those used for processing hams, picnics, and butts. Tongues are usually soaked over night in a strong pickle solution to loosen the mucous coating. They are then washed, cured, and cooked to an internal temperature of at least 152°F in the smokehouse. Not all tongues are cooked. Some are cured only and sold raw.

PICKLED PIGS FEET

Pickled pigs feet are processed according to one of two procedures, usually referred to as long and short cures. The long cure calls for preparation of an 80–90° salometer brine to which conventional amounts of nitrate and nitrite are added. The feet are immersed in the pickle and remain for 10 to 14 days. They are then removed, skinned, cut from toes to shank, and the entire foot cooked in 180°–200°F water until the meat is tender, usually 3 to 4 hr. After cooking, the feet are chilled in running water, then placed in a refrigerator to complete chilling. Chilled feet are split and semi-boned. They are then packed in 40–75 grain vinegar in jars. Pepper, bay leaves, and other spices may be added to the jar for appearance and flavoring.

The short curing procedure is sometimes referred to as the hot cure, because feet can be cured as they are cooked. Properly cleaned and chilled feet are immersed in pickle for 3 to 6 hr. Temperature of the pickle is raised gradually to approximately 180°F. The feet are cooked until tender, usually 3 to 4 hr, and then cooled in running water and packed in vinegar in jars.

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13

The Canning Process

The major reason for canning meat is to provide safe products that have desirable flavor, texture, and appearance. The considerations are similar to those of the entire commercial canning industry. However, the problems of meat canners are often more acute because meat products are low-acid foods. This chapter describes canning of both sterile and pasteurized meat products. In practice, complete sterility is seldom achieved. Usually, the thermal processing required to assure absolute sterility is so severe that the organoleptic characteristics of canned meat products are affected adversely. In many cases, microorganisms survive thermal processing temperatures, but remain dormant or are inhibited from germination by some other factor. In the trade, the terms commercially sterile or shelf-stable products are commonly used. A safe commercial process does not necessarily require complete destruction of microbial life.

Successful production of commercially sterile canned meat products requires that all viable microorganisms be either destroyed or rendered dormant. The process must also inactivate raw material enzyme systems. Commercially sterile canned meat products generally reach an internal temperature of at least 225°F, but this temperature may be as low as 215°F, depending on salt and nitrite content. This severe heat treatment may result in noticeable changes in flavor, texture, and color. Physical as well as chemical changes are functions of both the time and temperature to which the meat is subjected. To assure product safety, federal inspection regulations require samples of each processed lot be held at 95°F ± 2° for a minimum of 10 to 30 days before the cans leave the plant. Incubation time depends on the product. One can must be incubated from every retort load and for each 1,000 cans cooked in a hydrostatic cooker. At the end of the incubation period cans are examined for evidence of spoilage, as noted by end distortion of the cans. If none is found, the canned products are permitted to enter commercial distribution channels. The quality of canned meat products is highly dependent on the condition of the raw meat materials. Even though microorganisms that cause deterioration may be destroyed during processing, any flavor changes they induce cannot be reversed.

A. M. Pearson et al., *Processed Meats*

In contrast, some meat products merchandised in cans receive only a pasteurization process and are commonly referred to in the trade as perishable, which means they must be kept refrigerated. Even then, their shelf-life is usually considerably less than that of shelf-stable canned meat products.

Pasteurized canned meats are a compromise. Perishable or pasteurized canned meats are cooked to an internal temperature of at least 150°F, as required by federal inspection regulations. This results in canned products being free from any public health hazard, but does not result in complete destruction of all microbial contaminants. Therefore, pasteurized canned meats must be held under refrigeration. If they have been processed under sanitary conditions and properly refrigerated, it is quite possible for pasteurized canned meats to be both palatable and safe to eat for at least 2 years. Salt and nitrite present in the curing pickle contribute significantly to the safety of pasteurized canned meats.

The canning of meats or other products in which meat is a constituent, except pork and beans, if intended to be offered in interstate commerce, can be done only with approval of federal meat inspection authorities. In 1981, approximately 2.2 billion lb of meat and meat products, exclusive of soups and pork and beans, were canned. Table 13.1 shows some of the principal meat products that are canned and the amounts of each produced under federal meat inspection. These products comprise only 58% of all canned meat, which indicates the great variety of canned meats that are produced.

Canned hams, which are the only perishable products listed in Table 13.1, comprise 11.2% of all canned meat and rank third in amount produced. In recent years, there has been a rapid increase in production of canned pasta products with meat and in chili con carne, whereas the amount of canned hams produced has declined.

TABLE 13.1. Principal Canned Meat Products Produced Under Federal Inspection in 1981

Product	Amount (million lb)	% of Total canned meat
All canned meat	2,213	100
Pasta products with meat	380	17.2
Chili con carne	312	14.1
Canned hams	247	11.2
Meat stew	126	5.7
Vienna sausage	97	4.4
Hash products	73	3.3
Potted products and spreads	38	1.7
Tamales	22	1.0

CANS

Type of Cans

Five principal types of cans, as shown in Fig. 13.1, are used in the meat industry: (1) square and pullman base, (2) pear-shaped, (3) round sanitary, (4) drawn aluminum, and (5) oblong.

Square and Pullman Base. These containers are used primarily for pasteurized meats. The principal meats packed are chopped products such as spiced luncheon meat and chopped ham, corned beef for government contract packs, and boneless hams, particularly in the pullman style, where slices of sandwich dimension are desired by either consumer or institutional trade. Pullman-base cans are available in one oblong base and a number of heights. Fill weights for $4\frac{7}{8} \times 4\frac{5}{8}$-in. base pullman cans are given in Table 13.2.

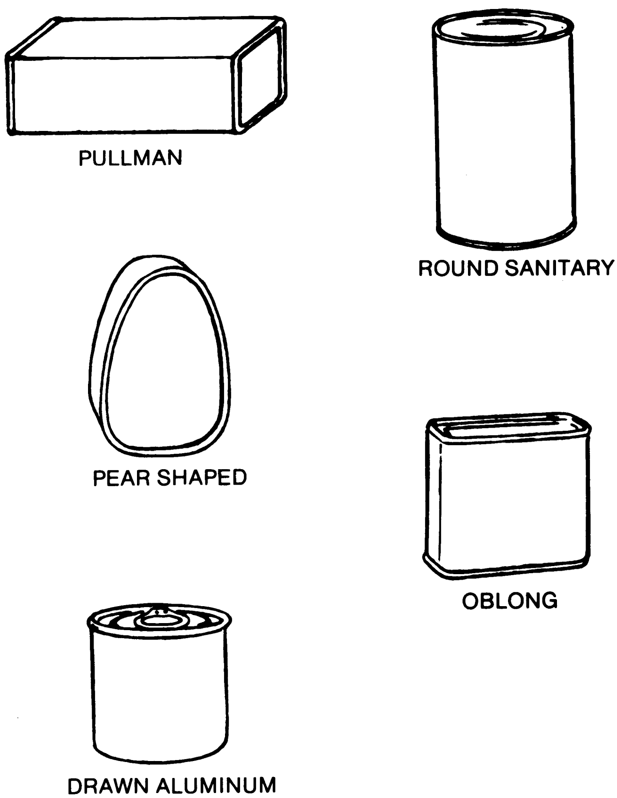

FIG. 13-1. Can styles.

TABLE 13.2. Fill Weights for 4⅞ × 4⅝ in. Pullman Cans

Can height (in.)	Range of fill-in weights				
	(lb)	(oz)		(lb)	(oz)
10½	7	8	to	7	14
11	7	15	to	8	5
11½	8	6	to	8	12
12	8	13	to	9	3
12½	9	4	to	9	10
13	9	11	to	10	1
13½	10	2	to	10	8
14	10	9	to	11	0

Pear Shaped. These containers are used to pack pasteurized hams and picnics. They are anodized and enameled, as are the square and pullman base containers. Recently, plastic containers constructed of high-density polyethylene have been used commercially. Some containers are manufactured with a barrier material to lower the oxygen transmission and so increase product shelf-life.

Pear-shaped cans come in four bases, as follows.

Minature Base.—1½-lb ham sections are packed in this can. Hams packed in these cans are generally given a sterile cook to make them shelf-stable.

No. 1 Base.—Available in various heights; this base can is usually used for sectioned hams. Most hams in this size can are given a pasteurizing cook for refrigerated storage.

No. 2 Base.—Available in various heights; both split and small whole hams are packed in this base can for the consumer trade. These hams are given a pasteurized cook.

No. 4 Base.—Available in various heights; whole hams are packed in these cans and given a pasteurizing cook. This size is furnished for both the consumer and slicing trade.

Approximate fill weights for pear-shaped cans are given in Table 13.3.

Round Sanitary. Cylindrical or round sanitary cans. as they are generally called, are available in a variety of diameters and heights to fit the broad line of canned meat products. They range in size from the 208 × 108 to the No. 10 cans used for institutional canned meat products. The major products packed in sanitary cans are chili, stews, hashes, and a variety of entree meat-base products.

Drawn Aluminum. Drawn aluminum cans are used principally for Vienna sausage, potted meats, and meat spreads.

Oblong. Oblong cans are used for sterile canned luncheon meats, generally in the 12-oz size. although some 7-oz cans are also packed. Luncheon meat cans are available in either tinplate or aluminum.

TABLE 13.3. Fill Weights for Pear-Shaped Cans

	Can height (in.)	Range of fill-in weight				
		(lb)	(oz)		(lb)	(oz)
Miniature Base Can (5¾ × 4 in.)	2 11/16	1	8			
No. 1 Base Can (7⅝ × 5⅜ in.)	3	3				
	3¾	4				
	3⅞	4				
	4	4				
No. 2 Base Can (9¼ × 6⅜ in.)	3¼	4	12	and	5	
	3½	5				
	4	6				
	4½	6	12			
No. 4 Base Can (10 11/16 × 7 9/16 in.)	3¾	7	11	to	8	3
	4	8	4	to	8	12
	4¼	8	13	to	9	5
	4½	9	6	to	9	14
	4¾	9	15	to	10	7
	5	10	8	to	11	0
	5¼	11	1	to	11	9
	5½	11	10	to	12	2
	5¾	12	3	to	12	11
	6	12	12	to	13	4
	6¼	13	5	to	13	13

Can Materials

Tinplate cans are made of thin sheets of steel coated with a very thin film of tin. The tin coating serves two purposes: (1) it covers the face of the steel sheet to prevent rusting, and (2) it acts as a medium by which parts of the sheet may be made to adhere by soldering. Can production is a high speed operation. Can-making machines, when linked together by mechanical conveyors, produce complete cans with side seams soldered and one end seamed at a rate of five per second.

The first number of the dimension of a round can denotes diameter and the second denotes height. The first digit of either number represents number of whole inches and the last two digits represent inches in sixteenths. Thus, a 401 × 411 can is $4\frac{1}{16}$ in. in diameter and $4\frac{11}{16}$ in. high. In the case of a pear-shaped can, the first number indicates length, the second width, and the third height. Table 13.4 gives the dimensions of some of the more commonly used cans in the meat canning industry.

To prevent interaction between a meat product and the metal, cans are generally coated on the inside with an organic material. The terms enamel and lacquer are used interchangeably with organic coating. These coatings are solutions of resins in organic solvents. Two general kinds of organic coatings are used in the food industry: (1) acid-resistant and (2) sulfur-resistant. Acid-resistant coated cans are used

TABLE 13.4. Dimensions of Cans Commonly Used in the Meat Canning Industry

Round Sanitary

Diameter		Height	Use	Nominal capacity Fl oz
208	×	109	Potted meat	3.2
208	×	207	Spreads, Vienna sausage	5.3
211	×	400	Chili, meat sauces	10.5
300	×	407	Chili, hash	14.6
401	×	411	USDA chopped meat, boned turkey	28.6
404	×	309	Stew, chili, hash	23.9
404	×	509	Stew, chili, hash	38.9
603	×	700	Various meat products for institutional use (known as No. 10 can)	105.1

Luncheon Meat and Pear-Shaped Cans

Length		Width		Height	Use	lb	oz
202	×	314	×	304	Oblong luncheon meat		12
400	×	400	×	602	Rectangular luncheon meat	3	
400	×	400	×	1110	Rectangular luncheon meat	6	
310	×	402	×	1208	Rectangular luncheon meat	6	
410[a]	×	414	×	1100	Pullman luncheon meat or whole ham	8	
512	×	400	×	212	Miniature base pear-shaped ham	1	8
710[a]	×	506	×	300	No. 1 base pear-shaped ham	3	
904[a]	×	606	×	308	No. 2 base pear-shaped ham	5	
1011[a]	×	709	×	400	No. 4 base pear-shaped ham	8	

[a] Containers made in various heights to accommodate several weight ranges of product.

primarily for fruits. Meat products are generally packed in cans that have been lined with a sulfur-resistant material. This is necessary because during the retorting operation, sulfur released from meat proteins will stain tinplate an unsightly black. Because solid meat products are frequently difficult to remove from cans, coatings containing a release agent are used to facilitate product removal. Pear-shaped and pullman base containers used for hams and other pasteurized canned products are lined with an organic coating containing a release agent. A reclinched or welded aluminum anode is also placed in each can used for cured meats. The aluminum corrodes preferentially and, in so doing, minimizes product discoloration as well as internal can corrosion caused by curing salts. An aluminum anode is seldom used for sterile products because the hydrogen evolved during high-temperature retorting and storage may reduce shelf-life.

Aluminum cans are not used as extensively as tinplate cans in the meat-canning industry. However, they are used by canners for certain products packed in shallow drawn cans, such as potted meats, meat spreads, and Vienna sausage. Although aluminum cans are more costly than tinplate, they offer certain advantages, such as lower shipping costs, resistance to sulfide and rust discolorations, and easier opening. They are especially popular when an easy-open, pull-type top feature is desired. The easy-open lid feature is probably the strongest selling point for aluminum cans. However, the development of steel cans with steel easy-open lids, with their slight economic advantage, is likely to detract from the popularity of aluminum cans. Meat products containing sodium chloride cannot be canned in bimetallic cans because of corrosion problems that result from electrolytic action.

Plastic may be used instead of cans. Although, strictly speaking, the products are not canned, they are processed in the same manner as canned meats. They can be made in any desired shape. The plastic material can be manufactured from high density polyethylene or from a mixture of nylon and surlyn. The latter has been widely used, coming in rolls that with special machinery can be made to fit the products. A schematic diagram of the equipment used to form the film into a package and seal it is shown in Fig. 13.2. At present, the nylon–surlyn film is being used for producing "cook-in" hams and poultry products. It is also being used for packaging of some semidry and dry sausage products. The hams packaged in the nylon–surlyn film are cooked in the package in the same way as canned hams and are sometimes called the "uncanned canned ham" because of the process. Although the nylon–surlyn package is used only for pasteurized or already relatively shelf-

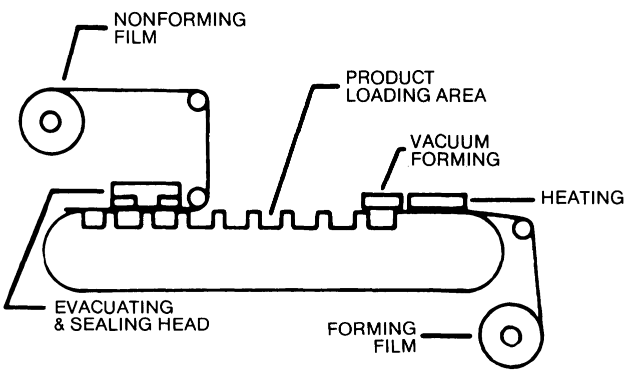

FIG. 13-2. Schematic diagram of dieless vacuum packaging equipment illustrating how the film is formed, the produced placed in the package, evacuated, and sealed. Heating of the film is an essential step before forming. Courtesy of Curwood Inc., New London, Wisconsin.

stable products, films are also produced that will stand the retorting process and can be used for sterile meat products.

RETORTS

The single most important phase of a sterile canning operation is retorting. The retort operation serves two purposes: (1) products are subjected to a high temperature for sufficient duration to destroy all organisms that might adversely affect consumer health, as well as other more resistant organisms that could cause spoilage under normal storage conditions, and (2) products are cooked so they can be eaten directly as they come from the can.

A retort is a steel tank in which metal crates or baskets containing the cans are placed for cooking and subsequent cooling. It is fitted with a cover or door which can be closed to provide a seal to hold the cooking or cooling pressure. Three types of retorts are used in the food industry: (1) nonagitating, (2) continuous agitating, and (3) hydrostatic.

Nonagitating Retorts

Most canned meat products manufactured in this country are cooked in nonagitating retorts. The term still or stationary is sometimes used to characterize the nonagitating retort. These retorts are closed-pressure vessels that operate in excess of atmospheric pressure and use pure steam or superheated water as the heating medium for cooking. The steam comes from an outside source, such as a steam boiler or generator. The first retorts using steam from an outside source were developed about 1875. Since that time, they have received universal acceptance. Nonagitating retorts function on a batch basis; that is, the retort must be loaded, then closed, and the entire batch cooked before a second batch of product can be put in. Nonagitating retorts can be vertical or horizontal. Figure 13.3 shows a vertical and Fig. 13.4 a horizontal retort. They are constructed for various maximum pressures, but standard construction used in the meat industry is 15 psi maximum operating pressure.

Vertical retorts are more efficient than horizontal ones with respect to the number of cans they will hold per unit of retort volume. Vertical retorts also occupy less floor space for a given capacity, but more mechanical handling of the baskets or crates is required. Horizontal retorts vary greatly in size and shape; some are round and others square with doors at one or both ends. They can be made larger than vertical retorts, so that carts or trucks can be moved in and out direct from the canning floor. Confusion can be minimized and efficiency increased by having doors at both ends, thereby allowing uncooked products to enter at one point and cooked products to be discharged at another.

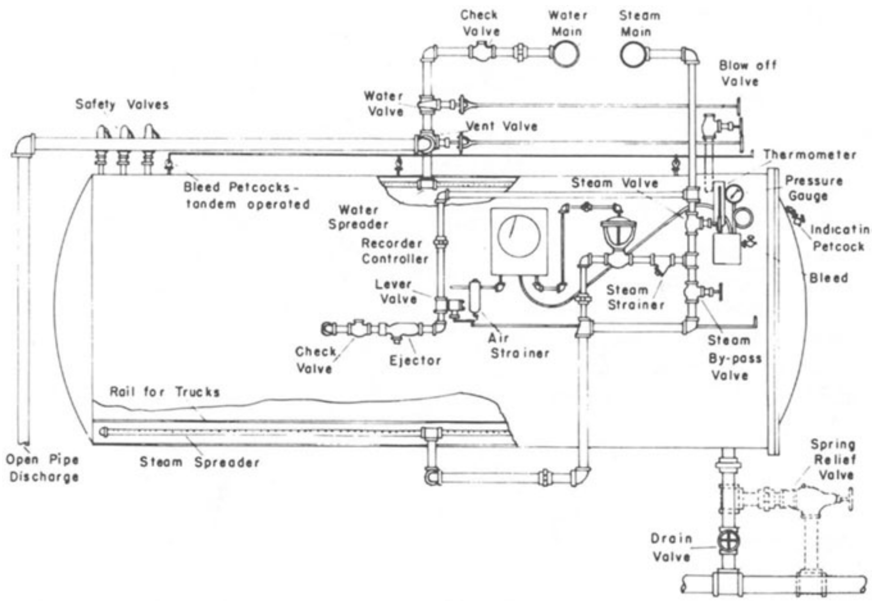

FIG. 13-3. Vertical retort with bottom steam inlet and air pressure for cooling. Courtesy of American Can Company, Barrington, Illinois.

Continuous Agitating Retorts

As the name implies, the cans are agitated while in the retort. This results in a shorter processing schedule, made possible by a faster rate of heat penetration into the meat. Continuous retorts are used to some extent for Vienna sausage and potted meats.

Hydrostatic Retorts

Hydrostatic sterilization is so named because steam pressure is maintained by water pressure. These retorts or cookers, as they are commonly called, are made up of water and steam chambers referred to as legs. Figure 13.5 shows a hydrostatic cooker. The temperature of the water in the water chamber varies from 60° to 260°F; that of steam in the steam chamber is controlled by pressure produced by the water chamber. Steam temperatures between 240° and 265°F are generally used. Operation of the hydrostatic cooker is basically as follows: cans are conveyed through the machine by means of carriers connected to chains. The cans enter a water chamber where the temperature is about 180°F. This is the down-traveling water chamber where the product temperature begins to increase. As the cans move down through this chamber, they encounter hotter water. In the lower part of the chamber, the water temperature reaches 225° to 245°F. Then, near the water seal area next to the steam chamber, the water temperature increasingly

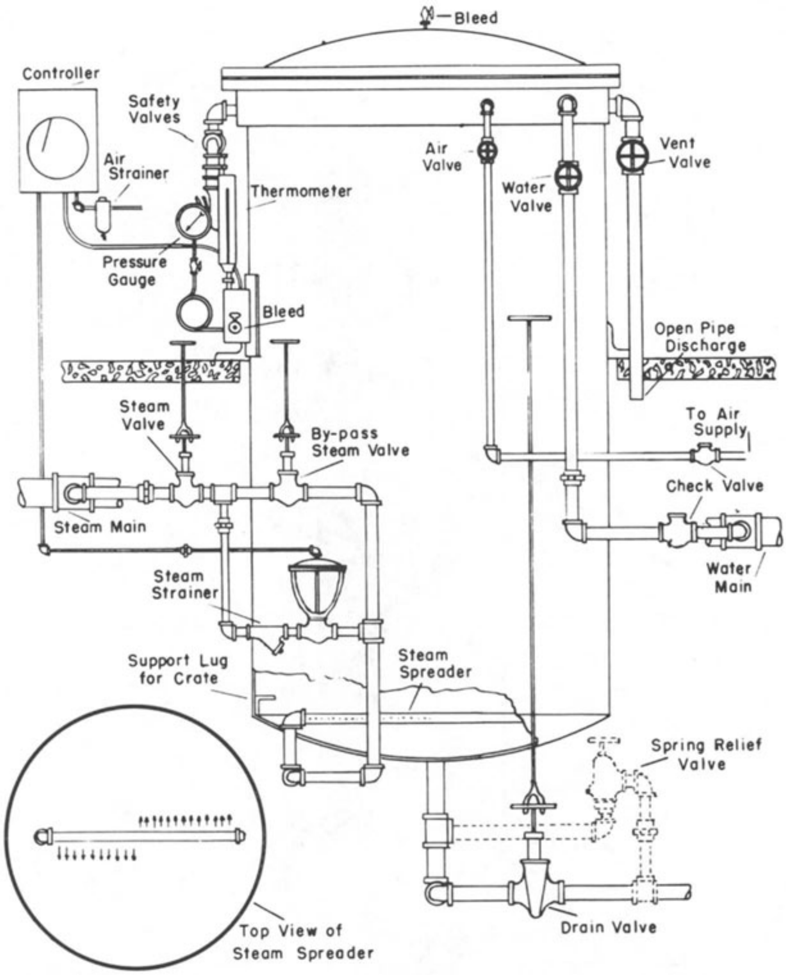

FIG. 13-4. Horizontal retort with steam injected air for cooling. Courtesy of American Can Company, Barrington, Illinois.

approaches that of steam. In the steam chamber, the cans are exposed to a temperature between 240° and 265°F. The temperature used depends on the product being cooked. Several models of these cookers are manufactured. In some, cans make two passes, one up and one down the steam chamber.

Hydrostatic retorts have several advantages over nonagitating retorts: (1) saving in floor space; (2) a great reduction in operating cost because steam and water costs are lower due to regenerative heating and cooling; and (3) greater capacity for high-volume operation. The main disadvantage of a hydrostatic retort is the large initial capital

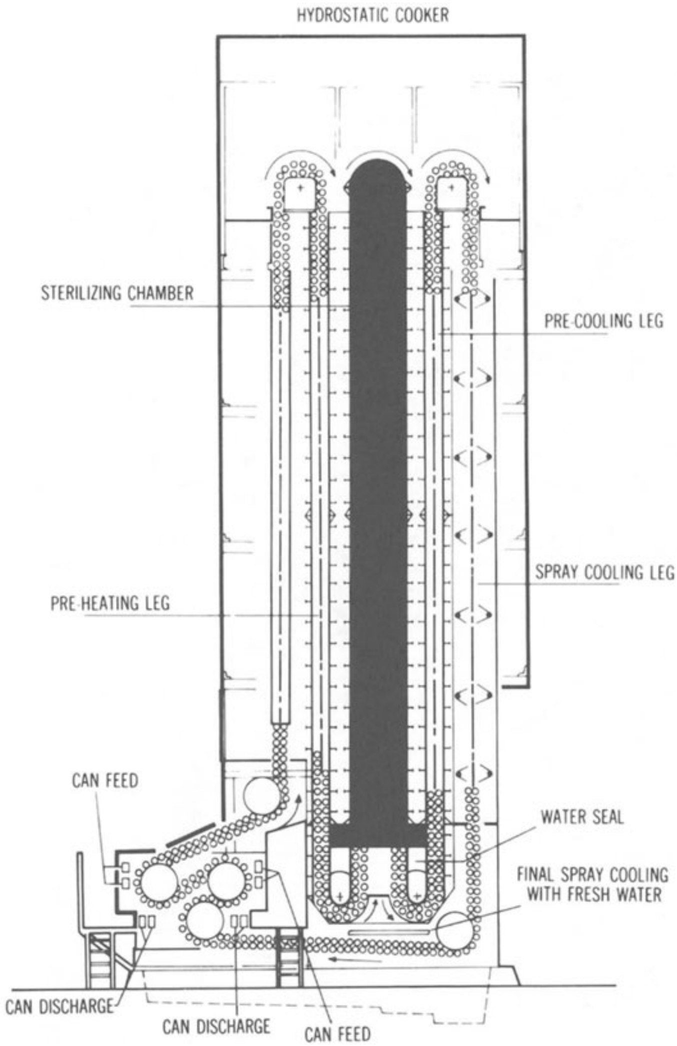

FIG. 13-5. Hydrostatic cooker.

investment required. Also, there is the disadvantage of limitation on sizes that can be cooked in any given unit.

Establishment of Retort Schedule

To establish a retort schedule for a sterile canned meat product, it is necessary to determine the rate of heat penetration at the slowest heating point in the can, this being the geometric center of the product.

Determination of heat penetration is done by fitting cans with needle-type thermocouples placed in the product. From temperatures recorded on a self-recording potentiometer, a temperature graph is obtained. With this information the lethal effect of a particular process can be integrated with respect to the thermal death time of a specific microorganism. The usual practice is to calculate this in terms of the destructive effect on *Clostribium botulinum* of an equivalent number of minutes at 250°F. This is expressed as the F_0 value. To better clarify F_0 consider the following example: if a heat penetration graph plotted for a process of 60 min at 240°F was converted into a graph based on the lethal rates compared to the effect on *Clostridium botulinum* of 1 min at 250°F and then integrated, a total value of about 7 could result. This would mean the process has an F_0 value of 7 or is equal in destructive effect on *Clostridium botulinum* to 7 min at 250°F, assuming instantaneous heating and cooling. Expressing a process by an F_0 value is really quite arbitrary. However, it is a useful way of expressing a process schedule in simple numerical form and also serves for purposes of comparison. As a general rule, the one basic criterion is that all canned foods having a pH of 4.5 or above must be given a minimum safe cook, sometimes referred to as a botulinum cook. For practical purposes, a botulinum safe cook is generally considered to be one having an F_0 of 2.78. However, this process does not necessarily ensure freedom from spoilage by organisms that are more heat-resistant than *Clostridium botulinum.*

PASTEURIZED CANNED PRODUCTS

Pasteurized canned hams and picnics are the two principal pasteurized canned meat products. Of these, canned hams are by far the more popular. Federal inspection regulations state that the word ham, without any prefix, may be used on labels only in connection with pork hams. The regulations further specify that preparation of hams for canning must not result in an increase of more than 8% in weight over the weight of fresh, bone-in, uncured hams. Compliance, as explained in Chapter 6, is determined by calculation from the results of chemical analyses. The protein constant or *k* factor for canned hams is 3.83. Federal regulations place the following additional restrictions on pasteurized products: (1) all products must be cured; (2) net weight of each canned product must be 12 oz or greater; (3) products must be cooked in cans to a center temperature of at least 150°F; (4) canned products must be labeled "Perishable—Keep Under Refrigeration"; and (5) canned products must be stored and distributed under refrigeration.

Hams and picnics to be canned are cured exactly as hams or picnics cured for other purposes. However, since canned hams and picnics do not experience a loss in yield during the cooking process, as do uncanned products, the amount of pump pickle must be restricted so that finished products will meet federal inspection regulations on increase in weight over fresh, bone-in, uncured products.

Weights of hams used for canning vary from 12 to 25 lb. On occasion, even heavier hams are used. The size of ham used depends to a large extent on the quality of the canned product desired. Both whole hams and sections are canned. When sectioned for canning, a ham is usually divided into either two sections (1) cushion and (2) knuckle, or into three sections (1) knuckle. (2) top, and (3) bottom. Shank meat is frequently placed in a ham to fill the cavity resulting from removal of the femur or leg bone. Here again, the inclusion of shanks depends on the desired quality of the finished product. If frozen hams are used, they must be thawed prior to pumping. This can be done by placing the hams in a refrigerated room long enough to thaw, or by placing them in a warm brine solution. A 15° salometer brine heated to about 100° is generally used. It takes about 12 hr to thaw a frozen ham in brine. However, thawing time depends on (1) size of the ham, (2) temperature of the ham at the start of thawing, and (3) capacity of the equipment.

CLOSING

Before closing the cans, large cuts of meat such as hams and picnics are pressed to ensure correct can fit and to eliminate air pockets. Pasteurized canned meats are closed on a vacuum closing machine with 18 to 25 in. of machine vacuum; but because of entrapped air within the can, final can vacuum will seldom exceed 2 to 5 in. All canned meat products, whether pasteurized or shelf-stable, should be cooked as quickly as possible after they are closed to assure that maximum quality is maintained.

PASTEURIZING COOK

Pasteurized canned meat products are cooked in 155°–170°F water in open cook tanks to an internal temperature of 150°–155°F. Table 13.5 shows retort schedules for several representative size pasteurized canned meat products.

COOLING

After the heat process has been completed, all canned meat products should be cooled as quickly as possible to a level at which cooking and quality deterioration stop, and below the range at which any surviving thermophilic bacteria can grow. After final cooling, temperature in the product center should not exceed 100°F, with 70° to 80°F being more

TABLE 13.5. Cook Schedules for Pasteurized Canned Meats[a]

Product	Can Size	Cook time (min)	Water temp. (°F)	Initial meat temp. (°F)
3-lb ham	1 base—300 high	120	165	35
4-lb ham	1 base—400 high	165	165	35
5-lb ham	2 base—308 high	165	165	35
8-lb ham	4 base—400 high	220	165	35
9-lb ham	4 base—404 high	255	165	35
10-lb ham	4 base—412 high	290	165	35
11-lb ham	4 base—500 high	330	165	35
12-lb ham	4 base—508 high	365	165	35
13-lb ham	4 base—600 high	400	165	35
8½ to 11-lb pullman	410 × 414 × 1200—1400	275	165	35
3-lb oblong luncheon meat	400 × 400 × 602	160	165	30
6-lb. oblong luncheon meat	400 × 500 × 1110	210	165	30

[a] Schedules based upon reaching can center temperature of 150°F as required by Federal Meat inspection regulations.

ideal. However, because the cans are wet, it is best to permit some heat to remain in them to accelerate evaporation of water. If water does not evaporate, rusting can occur which can affect can line sanitation and labeling efficiency. When cans are being cooled, they contract and are subjected to internal pressure changes. Under such conditions, even well-made seams may permit slight inward leakage. Thus it is necessary for the water used for cooling to be as near sterile as possible. To achieve the necessary microbiological quality, canning cooling water is chlorinated. For large-diameter cans and all products cooked in hydrostatic cookers, cooling must be done under pressure to prevent buckling of the can ends. Buckling is permanent deformation of can ends which can occur if the retort pressure is released suddenly after the cooking period. With pressure cooling, steam pressure is replaced by compressed air.

Sodium nitrite is frequently added to either the retort or cooling water to serve as a corrosion inhibitor. Sodium bisulfate is also permitted by federal inspection regulations. Nitrite and bisulfate retard the formulation of rust on meat containers not only during processing but also during subsequent storage. The exact mechanism by which nitrite and bisulfate function as inhibitors is not known, but it is thought they contribute to the development of a protective film. Although the concentration of nitrite or bisulfate necessary for effective inhibition varies depending on certain processing conditions, 600 ppm nitrite and 0.001% bisulfate in the process water will prevent external corrosion under the most severe processing conditions. To prevent accidental misuse of nitrite as table salt, federal inspection regulations direct that sodium nitrite be decharacterized with charcoal. Generally, 0.05% finely ground charcoal is used to change the color of nitrite from white to gray.

STORAGE AND SHELF-LIFE

Sterile canned meats should be placed in a cool. dry place since both relative humidity and temperature influence their keeping quality. The storage place must be dry, preferably no more than 30–40% relative humidity. This will prevent rusting of the cans and weakening of the fiber cases in which the cans are packed. Storage temperatures of sterile canned meat products should not be above 70°F, because higher temperatures markedly accelerate deterioration during storage, thus limiting shelf-life. In general, meat products stored at 70°F retain acceptable palatability characteristics for 4 to 5 years. If held at 40°F or below, even longer shelf-life will result.

Pasteurized canned products should be stored in a dry, refrigerated room at a temperature not exceeding 40°F. Properly handled pasteurized canned meat products packed in metal cans stored at 40°F or below will not show adverse quality effects for 2 years or more. However, for hams processed in plastic cans, shelf-life will generally not exceed 12 to 18 months before adverse oxidative changes involving surface color and flavor are noted.

ASEPTIC CANNING

In the normal retort canning process. meat products are cooked at temperatures well in excess of those consistent with maximum product quality. Aseptic canning was developed in an attempt to improve finished product quality. Aseptic canning refers to a method of sterilizing containers and products separately and then assembling them in an aseptic atmosphere to achieve a sterile package that can be stored at room temperature. The product to be canned is heated, while flowing continuously, to a temperature around 300°F. At this temperature, sterility is achieved in a very short time. In essence, aseptic canning involves (1) continuous, completely enclosed heat processing, (2) cooling of the product, and (3) filling and closing in a sterile container within a sterile atmosphere. Figure 13.6 shows a complete aseptic canning line. This processing out-of-the-can procedure permits subjecting all portions of a product to optimum conditions of time and temperature and in so doing avoids overcooking and the associated degradation of flavor, texture, and color. To this time, conventional aseptic canning procedures have not been readily accepted by most canners. The main reason is that aseptically canned products must be homoge-

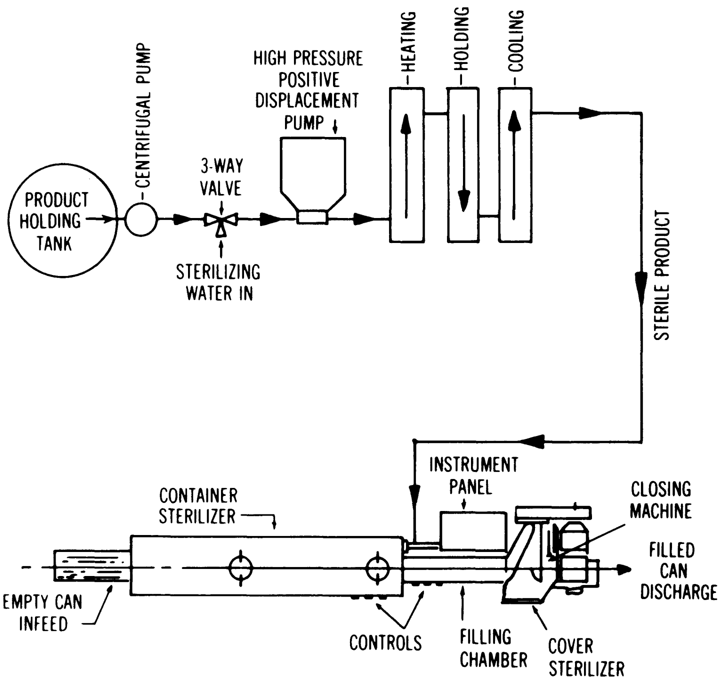

FIG. 13-6. Aseptic canning line.

neous and be able to flow readily, and meat products do not usually meet these requirements.

An alternative method for avoiding overcooking which has proved commercially feasible is the "Flash 18" process. The principal characteristics of the "Flash 18" process are filling of cans in a pressurized room under 18 lb air pressure at a temperature of 225°F and holding at this temperature for sufficient time to achieve sterilization. The cans are closed under the same conditions, thus eliminating retorting. The rapid cooking method used, under 18 lb pressure, gives the process its name, "Flash 18". Under normal atmospheric conditions it is not possible to fill cans at a temperature above 212°F. By raising air pressure in the filling and can-sealing room, the boiling-point temperature is raised, so it is possible to fill cans at much higher temperatures. When cans are closed with the product heated to around 255°F, sterility is achieved by retaining this temperature for a few minutes, whereupon the cans are cooled rapidly. Workers in the pressurized room must spend a short period of time in a pressure-adjusting airlock before entering and leaving the room.

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14

Canned Meat Formulations

In the meat-processing industry, the manufacture and marketing of canned meats and meat products is sometimes separated into two areas, (1) pasteurized and (2) shelf-stable products. Canning of pasteurized canned-meat products is generally closely associated with the manufacture of other pasteurized processed meat products. However, shelf-stable canned meats and canned-meat products usually fall under the heading of grocery products, and, in the largest meat-processing companies, are usually the marketing responsibility of a grocery products department. Invariably, all products handled by this department of a meat-processing company are shelf-stable.

This chapter provides formulations and processing directions for the manufacture of some of the best-known shelf-stable and pasteurized canned-meat products. With the exception of canned hams, the formulations are all expressed on the basis of a 100-lb meat block. Formulations shown in this chapter are meant to be representative of a wide variation in terms of meat as well as seasoning ingredients.

A word of caution is advised. The manufacturer of shelf-stable canned meats must constantly bear in mind that his products will not be stored under refrigerated conditions and may be held for many months, and perhaps years, before being consumed. Therefore, it is necessary that each product be retorted properly, and that, as a general rule, good manufacturing practices be followed to avoid the danger of botulism.

CORNED BEEF HASH

Federal Meat Inspection Regulations

Corned beef hash is the semisolid meat food product in the form of a compact mass which is prepared with beef, potatoes, curing agents, seasoning, and other optional ingredients. The finished product may not contain less than 35% cooked and trimmed beef, and the weight of the cooked meat used in this calculation may not exceed 70% of the weight of the uncooked fresh meat. The finished product may not contain more than 15% fat nor more than 72% moisture.

Corned Beef Hash

Ingredients	*lb*	*oz*
Cooked beef[1]	100	
Potatoes, dehydrated	130	
Beef broth	40	
Onions, raw	9	
Salt	4	
Ground white pepper		4
Sodium nitrite		0.25

[1]Cutter and canner grade. The beef should be cooked until it has lost 30% in weight.

Preparation

Meat. The chilled meat should be cut into strips approximately 2 in. wide by hand or with a rotary cutter. Grinding the meat through a 2 in. plate is an alternate method. Then the meat is placed in wire baskets or perforated crates for cooking in 180°F water for about 10 to 20 min. About 5 gal water are used for every 100 lb meat. Stainless metal, aluminum, or black-iron steam-jacketed kettles can be used, but copper equipment cannot. Since 30% shrink is required during cooking (as noted in the formulation), it will be necessary to check the weights frequently during cooking to establish the proper time.

After the meat is cooked, cool and either grind through a 3⁄16-in. plate or chop to achieve the typical texture for hash. Save the broth.

Potatoes. The potatoes should be soaked in hot water until they are rehydrated. About 1 part potato will combine with 4 parts water. This takes about 15 to 20 min.

Onions. The onions should be washed with cold water with a high-pressure spray. Blanch the onions in steam for 2 or 3 min to facilitate peeling and then pass them through a 3⁄8-in. plate. An equivalent amount of onion powder or onion flakes can be substituted for fresh onions.

The ground precooked meat is weighed and placed in a meat mixer. Sodium nitrite is dissolved in a little water and added slowly while mixing. The other ingredients are added and the mixing continued for about 3 min. If the hash is to be packed hot, the meat and broth should be as hot as possible with additional heat supplied by a steam jacket on the mixer, a steam jacketed preheater-conveyor, or similar means.

Canning

The hash should be kept at a minimum temperature of 120°F and well packed into the can to provide at least 5⁄16 in. head-space for "steam-vac" closure.

The cans should be closed using a machine vacuum of 15 in. or greater and either mechanical vacuum or "steam-vac" closures.

After the cans are closed, pass them through a detergent spray washer to remove grease and other materials. The washing should consist of a hot-water pre-rinse, spray wash, followed by a fresh, warm-water rinse. The cans must be processed immediately after closing. Following is a list of general can sizes, approximate net weights, and suggested processes for corned beef hash; however, the process conditions used must be based on the specific packing operation to ensure that an adequate process is used.

	Net Weight of Can			*Processing Time if cooked at*	
Can Size	*(lb)*	*(oz)*	*Initial Temp. of Hash*	*240°F (min)*	*250°F (min)*
211 × 300		7.5	100	75	55
			140	65	50
300 × 407		15.5	50	100	80
			100	95	75
			140	90	65
307 × 409	1	4.0	100	115	95
			140	110	90

Immediately after processing, the cans should be cooled in water until the average temperature of the contents reaches 95°–105°F to avoid thermophilic spoilage or can rusting.

Pressure-cooling is required for cans of greater than 307 diameter to prevent straining or buckling of the ends.

BEEF STEW

Federal Meat Inspection Regulations

Product labeled as meat stews shall contain not less than 25% meat computed on the weight of the fresh meat.

Preparation

Meat. The meat should be cut into 3-in. chunks and placed in wire baskets for cooking. Simmer the meat for approximately 15 min to produce the required 30% shrinkage (as noted in the formulation). The time required to cook the meat to achieve this shrinkage should be established by trial.

Stir the meat during cooking to obtain uniformly cooked pieces.

Beef Stew

Ingredients	*lb*	*oz*
Cooked beef[1]	100	
Diced potatoes, rehydrated dehydrated	80	
Water	75	
Gravy	70	
Diced carrots	52	
Chopped onions	14	
Flour (wheat or rice)	4	
Salt	2	
Ground black pepper		2

[1]The beef should be of canner and cutter grade from cows, steers, or heifers, free from cartilage and tendons, and trimmed of excessive fat. The beef must be cooked so that 30% shrink occurs.

After the meat has been cooked, dice the cooked strips into ¾-in. cubes. The broth should be saved to make the gravy.

Potatoes. The potatoes should be soaked in hot water until they are rehydrated and ready for use. They will yield approximately 300%.

Carrots. The carrots should be washed in cold water. When carrots are peeled by an abrasive method or hand-scraped, it will be necessary to give them a short blanch before peeling. About 2–4 min in boiling water is an adequate blanch. After blanching and peeling, trim away any damaged portions or blemishes and slice the carrots into ½-in. pieces.

Onions. The onions should be washed with cold water using a high-pressure spray. Blanch the onions in live steam for 2 to 3 min to facilitate peeling. Grind through a ⅜-in. plate and add them to the gravy.

Gravy

Ingredients	*lb*	*oz*
Broth from cooked meat	75	
Processed flour	5	
Salt	2	4
Ground black pepper		1

Preparation. Mix the flour with some cold water to make a smooth paste. Then dilute the paste by gradually adding the broth obtained when the meat is cooked. Add chopped onions, salt, and ground black pepper together while stirring constantly. Heat the gravy slowly to 180°F. If the color of the gravy is too light, it can be intensified by adding caramel coloring.

Canning

Fully enameled cans should be used. Before filling, the cans should be spray-washed with 180°F water according to meat inspection regulations.

Fill the cans with the meat and vegetables and then weigh. Add enough gray to fill the can. At this point, the gravy temperature should not be lower than 160°F.

Vacuum in the cans is usually obtained by filling level full with the product at a minimum temperature of 160°F using atmospheric pressure. However, the vacuum may also be obtained by machine vacuum, by "steam-vac" closure, or by thermal exhausting. A minimum machine vacuum of 15 in. is recommended. Steam-vac closures require that the beef stew be closed at a minimum temperature of 120°F and well packed in the can. When thermal exhausting is used, fill the cans at 160°F and exhaust for 7 to 10 min. The exhaust temperature should be 200°F.

After the cans are sealed, invert them in the retort cases to get a better mixture of the ingredients. A detergent spray washer should be used to wash the cans after they are closed.

The cans must be processed immediately after closing. Following is a list of general can sizes, approximate net weights, and suggested pro-

	Net Weight of Can			*Processing Time if cooked at*	
Can Size	*lb*	*oz*	*Initial temp. of stew (°F)*	*240°F (min)*	*250°F (min)*
211 × 300		7.5	120	85	65
211 × 400		10.5	140	80	60
			160	75	55
300 × 409	1		120	100	75
			140	95	70
			160	90	65
303 × 402	1		120	105	85
			140	100	75
			160	95	70
307 × 409	1	4	120	115	85
			140	110	80
			160	105	75
404 × 309	1	8	120	130	100
			140	125	95
			160	120	90
401 × 411	1	14	120	140	110
404 × 404	1	14	140	135	105
			160	125	95

cesses for canned stew; however, the process conditions used must be based on the specific packing operation to ensure that an adequate process is used.

After processing, the cans should be cooled immediately in potable and noncorrosive water until the temperature of the contents reaches 95°–105°F.

CHILI CON CARNE

Federal Meat Inspection Regulations

There is no federal standard of identity for canned chili con carne. Among the requirements of federal inspection regulations are the following: (a) chili con carne shall contain not less than 40% meat computed on the weight of the fresh meat; (b) chili con carne with beans shall contain not less than 25% meat; (c) head meat, cheek meat, and heart meat, exclusive of the heart cap, may be used to the extent of 25% of the meat ingredient under specific declaration on the label; (d) the mixture may not contain more than 8% individually or collectively of cereal, soya flour, vegetable starch, starchy vegetable flour, dried milk, or dried skimmilk.

Chili con Carne

Ingredients	*lb*	*oz*
Beef and beef by-products	100	
Beef broth or water	90	
Wheat flour	8	
Ground chili pepper	3	
Salt	1	
Ground domestic paprika		12
Ground cumin		9
Tomato paste		8
Ground oregano		4
Onion powder		4
Garlic powder		2

This formulation contains about 49% meat. Chili con carne with beans is made by adding 82 lb soaked and blanched red kidney beans (equal to about 40 lb dry beans) and 1 lb salt. This reduces the meat to about 32%. The beans should be blanched in boiling water for 5 min.

Preparation

The meat should be ground through a 3/8-in. plate and then braised in a steam-jacket kettle for 25 min at 220°F. Stir the meat to achieve uniform cooking. Add the flour, salt, spices, and water to the ground braised meat and cook all the ingredients together. A smooth paste should be made with the flour and water before the flour is added to the meat.

Canning

Fill the cans with the cooked chili and weigh. Close the cans by using the procedures described for beef stew. After the cans are filled and closed, they should be washed with a hot water and detergent spray.

Chili con carne varies in consistency and formulation. Thus, it is very important to note that any change that affects consistency will change the processing time.

			Processing Time if cooked at	
Can Size	*Net Weight of Can (oz)*	*Initial Temp. of Chili (°F)*	*240°F (min)*	*250°F (min)*
211 × 400	10.5	120	90	70
		140	85	65
		160	80	60
		180	75	55
300 × 409	16	140	100	75
		160	95	70
		180	90	65
303 × 402	16	120	120	90
		140	110	85
		160	105	80
		180	95	70

After processing, the cans should be cooled immediately in potable and noncorrosive water until the temperature of the contents reaches 95°–105°F.

VIENNA SAUSAGES

Federal Meat Inspection Regulations

There is no federal standard of identity for canned Vienna sausages. When shipped interstate, the product must be made in a federally inspected establishment and is subject to federal inspection regulations. Among these are the following: (a) there can be only 10% added moisture in the final product; (b) a statement regarding the packing medium, such as water or brine, must appear on the label; (c) the weight stated on the label is the drained weight; (d) cereal or milk powder, when used, must be limited to 3.5% and the label must state

"Vienna Sausage, cereal added." If more than 3.5% cereal is used, the product must be labeled "Imitation."

Vienna Sausages

Ingredients	*lb*	*oz*
Bull meat	50	
Beef trimmings	20	
Regular pork trimmings	20	
Beef hearts	10	
Crushed ice or cold water	15	
Salt	3	
Sugar		6
Ground pepper		6
Ground mustard		4
Sodium nitrite		0.25

Preparation

Even though Vienna sausages are canned, prepare the Vienna sausage emulsion following the procedures used to manufacture frankfurters. After stuffing into casings, Vienna sausages are either linked or simply looped over smoke sticks. After cooking, the sausages are cut into the lengths required for canning.

Canning

Key-opening cans are sometimes used for Vienna sausages. In this case, cans made from plain hot-dipped or electrotin plate bodies and enameled electrotin plate ends are recommended. For non-key opening cans, enameled electrotin plate may be used for both bodies and ends. Aluminum pull-top cans are frequently used for canned Viennas today. Before filling, spray wash the empty cans with 180°F water in accordance with federal meat inspection regulations.

Fill the cans with the required number of sausages. Then fill the remaining space with boiling water. The sausage strands are usually cut so seven pieces will weigh 4 to 4⅛ oz. The links lose approximately 0.25 oz during retorting, but regain most of this weight after 72 hr. The all-meat sausage continues to gain slowly for several weeks but rarely gains more than 0.25 oz. Viennas formulated with cereal may pick up 0.5 oz or more over a period of several weeks.

208 × 208 cans are usually prepared by filling completely with 190°–200°F water and closing atmospherically. Larger cans are filled with cold water and closed under as high a mechanical vacuum as possible, with excess water removed. After the cans are filled and closed, wash

and then rinse in warm water. The filled cans should be retorted immediately. Following is a list of general can sizes, approximate net weights, and suggested processes for canned Vienna sausages.

Can Size	Net Weight of Can (oz)	Initial Temp. of Fill (°F)	Processing Time if cooked at 225°F (min)	230°F (min)	240°F (min)
208 × 208	4	70	65	45	30
211 × 400	9	70	80	60	40
401 × 411	24	70	180	135	90
404 × 404	24	70	180	135	90

After processing, cool the cans immediately in potable and noncorrosive water until the temperature of the contents reaches 95 to 105°F.

MEAT BALLS WITH GRAVY

Federal Meat Inspection Regulations

Meat balls with gravy consist of ground meat which has been mixed with bread crumbs, onion, and spices, formed into spheres and placed in a gravy. There is no federal standard of identity for canned meat balls with gravy. A regulation of the Federal Meat Inspection Service states that beef with gravy cannot be made with beef which, in the aggregate for each lot, contains more than 30% trimmable fat.

Meat Balls

Ingredients	*lb*	*oz*
Cow meat	100	
Bread crumbs	5	8
Salt	1	
Onion powder		12
Pepper		4

Preparation

The beef is ground through a ¾-in. plate. Then the other ingredients are added and the mixture is reground through an ⅛-in. plate. The meat balls may be formed by molding by hand, mechanically, or by a sausage stuffer. When a stuffer is used, the meat is put through a 1½ in. diameter horn onto trays. It is then cut into the desired lengths and formed by hand or mechanically. Raw meat balls should be about 1¼ in. in diameter and weigh about 1 oz, and should be floured lightly before being precooked. Excess flour should be removed by passing the meat balls over a shaker screen.

The meat balls may be canned either precooked or raw. For precooking, pass them through hot vegetable fat at a temperature of 375°F or through a gas flame or electrically heated oven. The time required to deep-fat fry is approximately 1 min; oven-cooking requires 10 min. This results in a weight loss of approximately 15%.

Gravy

Ingredients	*lb*	*oz*	*gal*
Beef stock			10
Flour	5		
Beef fat	2		
Salt	1	4	
Beef extract	1	2	
Onion powder		12	
Caramel coloring	6		
Celery salt	8		
Pepper	6		

Preparation

Either water or beef stock prepared by cooking 20 gal cold water and 100 lb. raw bone may be used. The bone should be split to expose the bone marrow, as this enriches the flavor of the stock. The bones should be simmered for approximately 4 hr.

The flour should be mixed with a portion of cold water to make a smooth paste. Then beef fat is added to the paste. The paste is gradually diluted by adding the filtered beef stock. All the other ingredients are added with constant stirring until blended thoroughly. Bring the gravy to a simmering temperature with constant agitation. Continue agitation during filling.

Canning

Fully enameled cans should be used. Prior to filling, they should be spray-washed with 180°F water. Ten precooked meat balls weighing about 8⅛ oz are placed in a 300 × 407 can and the can is completely filled with about 7½ oz gravy. The gravy should be maintained at a temperature of at least 160°F. The weight of the meat balls should be about 40% of the net weight of the container after processing. Hot gravy may be added by means of a pulp or plunger-type filler, depending on consistency.

Vacuum in the cans may be obtained by filling at a minimum product temperature of 160°F using atmospheric closure. Steam-vac closure may be used provided that the product is closed at a minimum temperature of 120°F and is well packed in the can with a minimum head space of 5⁄16 in.

Pass the cans through a detergent spray washer after closure to remove grease and other materials adhering to the outside of the cans.

The cans should be stacked in a crate in a way to permit free circulation of steam throughout the retort load. Following is a list of can sizes and approximate net weights and suggested processing schedules.

				Processing Time if cooked at	
Can Size	*Net Weight (lb)*	*(oz)*	*Initial Temp. of Contents (°F)*	*240°F (min)*	*250°F (min)*
211 × 304		8	120	80	60
			140	75	55
			160	70	50
211 × 400		10.5	120	80	60
			140	75	55
			160	70	50
300 × 409	1		120	95	70
			140	90	65
			160	85	60
401 × 211	1		120	100	75
			140	95	70
			160	90	65
307 × 409	1	4	120	110	85
			140	105	80
			160	100	75

Immediately after processing, the cans should be cooled in water until the average temperature of the contents reaches 95 to 105°F.

SLICED DRIED BEEF

Federal Meat Inspection Regulations

Canned, sliced, dried beef is prepared from dried, cured, smoked beef rounds. There is no federal definition or standard of identity for sliced dried beef.

Dried Beef

Ingredients	*lb*	*oz*
Meat: beef round sections (insides, outsides, knuckles)	100	

Preparation

Either fresh or frozen beef rounds can be used. Fresh beef should be chilled to an internal temperature of 38°F before curing. Frozen beef should be thawed. The best weight per piece is approximately 12 lb.

Pickle Formula

Ingredients	*lb*	*oz*
Water	42	
Salt	12	
Sugar	5	
Sodium nitrate		1.5

Processing

Beef rounds are sprinkled lightly with fine salt and packed in vats or tierces and covered with pickle. About 5 gal pickle are used for 100 lb beef. The beef is cured for 7 days per lb at 38°F. A 12-lb piece should be cured for approximately 84 days. The meat should be overhauled at 10, 25, and 40 days during the curing period. After the beef has been cured, it is soaked in water at approximately 60°F for 24 hr to prevent salt stains from appearing during the smoking and drying operation. The water should be changed at 6-hr intervals to ensure uniform soaking. After soaking, the meat is air-dried thoroughly and placed in a smokehouse.

Drying and Smoking

The smokehouse should be heated to approximately 110°F and meat held at this temperature for 12 hr. The temperature is increased gradually to 132°F at the end of 40 hr. During the first 24 hr of smoking, drying must be controlled so that moisture is removed from the surface by evaporation as rapidly as it appears, but avoiding formation of a dry crust. On about the second or third day, smoke is introduced into the smokehouse and the meat is subjected to a light smoke for 3 to 5 hr. By the end of the drying and smoking period, an internal meat temperature of 120°–125°F should be reached. Drying and smoking time should average 4 to 6 days. At the end of this period, the beef is cooled in a hanging room. Product weight loss during drying and smoking should be about 35%. Finished dried beef should contain approximately 50% moisture and 10% salt.

The cured dried beef, after being well chilled, is sliced to a thickness of 1/32 to 1/64 in.

Canning

Filling of the cans is a hand operation. Vacuum in the cans is obtained by closure in a vacuum seamer. A minimum machine vacuum of 25 in. is suggested for smaller cans. A machine vacuum of 20 in. is suggested for 603 × 700 cans. To facilitate slice separation, the cans may be sealed in a carbon dioxide or nitrogen atmosphere.

The following table shows typical cans used to pack dried beef and the product weight they contain.

Can Size	*Net Weight (lb)*	*(oz)*
202 × 214		2
211 × 400		7
404 × 200		9
404 × 402	1	8
603 × 700	6	

It is important that the cans be completely dry. It is not usually necessary to wash the filled cans.

No retorting of the filled and sealed cans is required if the beef is dried sufficiently. The beef should have a moisture content of approximately 50% and a salt content of 10%.

LUNCHEON MEAT

Federal Meat Inspection Regulations

Canned luncheon meat is a ready-to-eat finely ground or chopped product. It is generally made from pork, although beef, veal, and lamb may be used. There is no federal standard of identity for luncheon meat. Federal inspection regulations state that to facilitate chopping and to dissolve the curing agents, water or ice may be used during preparation; but, the total amount of water cannot exceed 3% of the ingredients, and its presence must be declared.

Luncheon Meat

Ingredients	*lb*	*oz*
Picnics	70	
Butts	15	
Shanks	15	
Salt	3	8
Sugar	2	
Sodium nitrite		0.25

The fat content of the meat block should not exceed 30% of the product. For pasteurized products, sugar (sucrose) can be replaced by corn syrup solids and dextrose to improve yields. The quantity of corn syrup solids is limited to 2% of the total ingredients. Therefore, dextrose is usually added in addition to the corn syrup solids to provide the original sweetness level obtained by sucrose. Sugar is important, since it masks the salt flavor. The salt content must be maintained at a sufficiently high level because of the low sterilizing value of the cooking process. A 6% salt-to-moisture ratio in the product is suggested. Although federal regulations allow the addition of 3% water, the amount of added water is calculated by analysis and depends on the moisture-protein ratio of the meat ingredients.

Preparation

Grind the meats through a ⅜-in. plate and then mix meat, salt, sugar, and nitrite in a vacuum mixer for 5 to 8 min under 26–28 in. of vacuum. The nitrite should be dissolved in a small amount of water to aid proper distribution. To minimize purge in the can, the mix should be maintained at 28°–30°F. Frozen meats or dry ice can be utilized to help achieve this temperature.

Canning

Enameled cans should be used for sterile luncheon meat. The enamel contains a release agent to facilitate removal of the loaf. Cans made with either plain or enameled bodies and enameled ends are recommended for pasteurized luncheon meat. All enameled cans for pasteurized products are fitted with an aluminum anode to lessen corrosion and subsequent discoloration. Before filling, the cans are washed with a spray of 180°F water.

Filling of larger cans (3 to 8 lb) can be done with a sausage stuffer having a special attachment to deliver definite volumes. The cans should be pressed firmly onto the filling attachments to avoid air pockets. Small cans (12 oz) are filled with automatic fillers attached to sausage stuffers.

Vacuum in the cans is obtained by mechanical vacuum closure. A machine vacuum of 25 in. is suggested. High mechanical vacuum closure depends on proper vacuum mixing and filling to prevent the product from being drawn out of the can. Avoid spreading the meat over the entire area and closing any passages for removal of air. The two wide sides of the closed rectangular can should show distinct concavity. After closure, the cans should be passed through a detergent spray washer to remove grease and bits of product adhering to the exterior of the cans. The washing operation should consist of a hot-water pre-rinse and a detergent spray, followed by a warm fresh-water rinse. There should be no delay in placing the closed cans in the retorts and starting the process.

Processing

Sterile. A 12-oz oblong can is used for all domestic packs of commercially sterile meat products that are stored without refrigeration. Any size can may be given a commercially sterile process, although this type of process is usually limited to 12-oz cans because of the severe heat treatment required for larger cans. Following is a list of can sizes and suggested processing conditions for sterile luncheon meat.

			Processing Time if cooked at		
Can Size	*Net Weight (oz)*	*Initial Temp. of Contents (°F)*	*225°F (min)*	*230°F (min)*	*240°F (min)*
300 × 308	12	45	90	80	70
115 × 312 × 310	12	45	90	80	70
202 × 314 × 304	12	45	90	80	70

Pasteurized. Pasteurized luncheon meat is usually packed in the larger 3- and 6-lb oblong cans or in square-base 4 × 4 containers made in heights to hold 3, 6, or 6½ lb of product. Pasteurized luncheon meat must be stored under refrigeration. The label must state "PERISHABLE—KEEP UNDER REFRIGERATION." Pasteurized canned products should be cooked in water to an internal temperature of 160°F. Following is a list of can sizes and suggested processing conditions for pasteurized luncheon meat.

	Net Weight			*Processing Time if cooked at*	
Can Size	*(lb)*	*(oz)*	*Initial Temp. of Contents (°F)*	*165°F (min)*	*170°F (min)*
310 × 402 × 608 (oblong)	3		30	220	180
310 × 402 × 1208 (oblong)	6		30	250	205
400 × 400 × 1110 (4 × 4)	6		30	300	245
400 × 400 × 1208	6	8	30	300	245

Immediately after processing, the cans should be cooled in water until the contents reach 100°F. Pressure cooling is required for the round or rectangular cans larger than 307 diameter to prevent straining or buckling of the ends. Pasteurized luncheon meats should be chilled further by holding at 38°F or below.

POTTED MEAT

Federal Meat Inspection Regulations

No federal standard of identity exists for potted meat; however, inspection regulations do not allow the use of extenders unless their presence is made part of the product name. As an example, product containing up to 5% cereal must be labeled POTTED MEAT, CEREAL ADDED. The amount of water added to potted meat must be limited to that necessary to replace the moisture lost during processing.

Potted meat products may be prepared from a variety of materials. The formulations are varied and quite elastic. Products usually contain fresh or cured beef or pork together with meat by-products.

Potted Meat

Ingredients	*lb*	*oz*
Cow meat	30	
Regular pork trimmings	20	
Pork tongue trimmings	25	
Beef hearts	15	
Beef tripe	10	
Salt	1	8
White pepper, ground		6
Mustard		0.8
Paprika		0.8
Nutmeg, ground		0.4
Sodium nitrite		0.12

Preparation

The tongue trimmings, heart, and tripe are parboiled in sufficient water to cover them and simmered for approximately 1 hr at 185°F until tender. The time will depend on the size of the pieces of meat. During parboiling, the meat may be held in wire baskets or crates.

The cooked meat is ground through a ¾-in. plate. Place all the meats together with all the other ingredients in a chopper and chop to a smooth paste. Broth from cooking the by-products or water is added during the chopping operation to give the product the desired consistency. The amount of water or broth to be added cannot be standardized, since the meat ingredients vary in their binding power. The formulas are generally flexible enough to utilize whatever meat ingredients are available. Judgment of the quantity of water to be added to maintain a uniform consistency is a matter of experience.

To prevent possible black iron sulfide formation, tripe should be placed in 50-grain vinegar for 10 min. This will neutralize any alkali which may remain from the tripe washing operation.

Canning

Cans can be filled with the meat paste by either of the following methods: (1) heat the meat paste in a steam-jacketed kettle to 160°F and pump the heated product to the filler; or (2) heat to 160°F while the product is moved through a mixer-preheater or conveyor equipped with a steam jacket. Mechanical fillers can be used because of the consistency of the product. Minimum head-space and maximum can vacuum are desirable to prevent air discoloration on the surface of the product.

Vacuum or steam-vac closure should not be used for potted meat because the cans are usually filled completely. Instead, the proper vacuum is obtained by filling the cans with the meat paste at a minimum closing temperature of 160°F. After the cans are closed, they are passed through sprays of hot water to remove grease and other extraneous materials from the outsides of the cans.

As soon as the cans are closed, they should be placed in a retort and cooked. The following is a list of cans frequently used and suggested processing schedules.

Can Size	*Net Weight (oz)*	*Initial Temp. of Contents*[1] *(°F)*	*Processing Time if cooked at* 240°F (min)	250°F (min)
202 × 115	3	120	65	40
		160	60	35
208 × 109	3¼	120	65	40
		160	60	35
208 × 208	5½	120	80	50
		160	75	45
300 × 102	3	120	60	35
		160	55	30

[1]Initial temperature is the average temperature of the can contents at the time the steam is turned on for the process.

Immediately after the cans are retorted, they should be cooled in cold water until the average temperature of the contents reaches 95°–

105°F. Cans of greater than 307 diameter should be pressure cooled to prevent straining or buckling of the ends.

CANNED HAMS, PASTEURIZED AND STERILE

Federal Meat Inspection Regulations

Federal meat inspection regulations allow canned hams a maximum weight increase of 8% over the weight of the fresh uncured ham. To help reduce liquid purge during cooking, regulations allow the use of an approved phosphate. Finished hams may contain no more than 0.5% added phosphate.

Only boneless hams, either whole or sectioned, are canned. Since canning does not improve the quality of the ham going into the can, hams selected for canning should be representative of the quality product desired.

Pickle Formula

Ingredients	*lb*	*oz*	*gal*
Salt	150		
Phosphate	50		
Sucrose	37	8	
Sodium nitrite	2		
Water			100

Preparation

Artery- or multiple needle-injection methods are used to pump hams with pickle. For maximum quality in the finished product, the pumped hams should be placed in cover pickle and allowed to cure for a minimum of 3 days prior to being canned. Gain in weight due to the cure ingredients must not exceed 8%.

Smoking

Most canned hams are not smoked. However, if smoke flavor is desired, the hams can be placed in a 130°–140°F smokehouse and subjected to smoke for 1 to 3 hr. An alternative to natural smoke is liquid smoke, either in the pump pickle or applied as a dip or spray. With exception of the cooking to which the hams are subjected if they are smoked, hams to be canned are not cooked prior to canning.

Canning

Two styles of cans are used for canning hams: (1) pullman base and (2) pear-shaped. These are described in detail in Chapter 13, along with dimensions and specific uses.

Pullman base cans are available in a number of heights and one base. This style is used for canning hams to be used primarily for slicing in sandwich dimensions.

Pear-shaped cans come in four bases. *Miniature Base:* 1½ lb ham sections; generally given a sterile cook. *No. 1 Base:* available in various heights; usually used for sectioned hams; given a pasteurizing cook. *No. 2 Base:* Available in various heights; both split and small whole hams for consumer trade; given a pasteurized cook. *No. 4 Base:* available in various heights; whole hams for both consumer and slicing trade; given a pasteurizing cook.

To prevent product discoloration, ham cans are normally anodized and have an inside enamel coating on bodies and ends. Anodized cans have an aluminum square welded to the inside of the bottom end.

Filling and Pressing. Cans should be washed in 180°F water before being filled. Hams or ham pieces are weighed after final trimming and the cans filled by hand to the desired weight. The cured hams are pressed to the can shape with a ham press. Hams should be cold when pressed to maintain shape better and to avoid problems during vacuum closure. Proper pressing is necessary to achieve the needed vacuum in the cans to avoid double seaming. Automatic can vacuum presses operated at 25 in. should be used.

A small amount of dry granular high-bloom gelatin is placed in the can after the can is filled. This should be done only for hams to be given a pasteurizing process for the purpose of partially solidifying cooking purge. Cook-out or purge in sterile processed hams is so great that it is not practical or appealing to solidify the liquid portion with gelatin. The amount of gelatin to use in a can will vary with the size of the ham; generally no more than 1 oz is needed for the larger hams. The gelatin should be placed over the top of the ham after pressing. A small portion should also be placed in the aitch bone cavity to bind the meat in this area.

Closing. Wipe the flange area of each can body to remove any extraneous matter before the lid is seamed. Close the cans under vacuum in a vacuum closing machine. Chamber vacuums of 25 in. or more should be used during the seaming operation to maintain maximum vacuum in the cans and to avoid "loose tin," which Federal meat inspection regulations prohibit. Loose tin refers to tinplate body panels not pulled in tight against the meat. Pullman hams require ½ to ¾-in. head space for proper vacuum closure.

Processing

Two methods of heat processing are employed for the canning of hams: (1) a low temperature pasteurizing process for perishable products to be held under refrigeration, and (2) a high-temperature sterilizing process for products to be stored at room temperature. Hams weighing 3 lb and over are generally given a pasteurizing process because the severity of the cook required to produce commercial sterility causes excessive moisture cook-out and shrinkage of the ham. Hams under 3 lb are generally given a sterile cook. However, there is no hard-and-fast rule regarding this matter, and there is some overlap in both directions.

Pasteurized. Pasteurized canned hams are cooked in agitated water at 160°–170°F until the can center reaches a minimum of 150°F, preferably 160°F. To prevent overcooking, different size cans should be cooked in different cook tanks. Processing times for pasteurized canned hams are as follows.

Can Base	*Initial Ham Temp. (°F)*	*Cook Water Temp. (°F)*	*Approx. Cook Time to Reach 150°F Internal Temperature (min/lb of meat)*
No. 1	50	160	47
(7⅝ × 5⅜ in.)	50	165	41
	50	170	37
No. 2	50	160	39
(9½ × 6⅜ in.)	50	165	35
	50	170	32
No. 4	50	160	33
(10 11/16 × 7 9/16 in.)	50	165	29
	50	170	26

Following cooking, the cans should be chilled rapidly in cold water to an internal temperature of 100°F. Cans should then be placed in a cooler at 38°–40°F for further cooling and storage. Canned pasteurized hams must be labeled PERISHABLE—KEEP UNDER REFRIGERATION.

Sterile. Canned hams to be sterilized so they can be stored without refrigeration are cooked in a conventional retort with steam. The following schedule can be used to process sterile canned hams.

Can Base	*Initial Temp. (°F)*	*Retort Temp. (°F)*	*Processing Time (min)*
Miniature	40	230	160
(5¾ × 4 in.)	40	240	110

Following retorting, the cans should be pressure-cooled in water until the temperature of the contents is 95°–105°F.

PLASTIC PACKAGED HAMS

These hams, as mentioned in Chapter 13, are referred to as "cook-in hams," since they are packaged in plastic and cooked like canned hams. Although the technology is available to make shelf-stable hams, most of those products are pasteurized. The plastic used for packaging of pasteurized hams is usually nylon and surlyn and produces an attractive product without any purge, since the hams are boned, cured, and tumbled and/or massaged prior to being packaged and heat processed.

Preparation

Boning and curing are carried out as in other hams, and the same precautions apply. Since these hams are tumbled or massaged, they take up the cure and are claimed to be juicier and more flavorful than conventionally canned hams. They have little purge and make an attractive high yielding product. They may be made with or without added water and should be labeled to meet Federal meat inspection requirements.

Packaging

The hams are packaged with the thermoform equipment described in Chapter 13 (Fig. 13.2). This equipment uses rolls of nonforming and forming film to form the plastic containers or "plastic cans." The containers are shaped to fit tightly around the product, with the forming film being used for this purpose and the nonforming film serving as the bottom. The package is evacuated and sealed at the same station of the machine, which has been specially developed for this purpose.

Processing

The same heat processing procedure is used to produce plastic canned hams as for conventional canned hams. These hams, which are also called "uncanned canned hams," are cooked in agitated hot water at a temperature of 160°–170°F until the temperature in the center of the can reaches a minimum of 150°F, or preferably 160°F. Cook times are similar to those for the same size canned hams, although thermal transfer properties are slightly different from metal cans. In any event, thermocouples should be used to establish actual temperatures achieved in each batch.

The hams should be held in a cooler at 38°–40°F and should be labeled PERISHABLE—KEEP UNDER REFRIGERATION. The length of storage life of these products has not been determined. However, they have been shown to be stable under refrigeration for periods up to 6 months. It is probable that longer storage periods can be used, but this must still be established.

15

Restructured Meat Products

There has long been an interest in producing steaks, chops, and oven roasts from entire carcasses, but the amount and distribution of connective tissues and fat in the animal body has made this impossible without disassembling and reforming of the meat into boneless restructured items. Production of boneless cuts or grinding of the muscles to form a rather homogenous mass have represented attempts to achieve this end, but either could not be used for all cuts or else lacked the characteristic structure of steaks and roasts that made them desirable to the human diet. Until recently, sausages and other ground meat items represented the major developments in this area. However, equipment has now been developed that makes it possible to disassemble the carcass and reassemble it in a way that gives it a texture similar to the more desirable steaks, chops, and roasts.

As already indicated in Chapter 7, in its broadest sense, any meat product that is partially or completely disassembled and then reformed into the same or a different form is restructured. This definition would not only include all sectioned and formed meat products, but all sausages as well as a variety of other products. For clarity and ease of discussion, sectioned and formed meat products and sausages are discussed separately in Chapters 7 and 9, respectively, other restructured meats will be discussed in this chapter. The term restructured meats as used here will include those products other than sausages and sectioned and formed meats.

There is a great deal of interest in production of restructured meats, and it has been targeted for expansion by some segments of the meat industry.

PROCEDURES

There are three basic procedures that can be utilized in the production of restructured meats: (1) chunking and forming: (2) flaking and forming, and (3) tearing and forming. The first two procedures have been widely used and are increasing in importance. The third procedure has not yet been fully developed and requires special equipment that tears the meat fibers apart and then reforms them into shapes resembling intact cuts. Each of these procedures will be discussed briefly from the standpoint of the principles involved, the methods utilized, and the advantages and disadvantages.

Chunking and Forming

Chunking is accomplished by passing the meat through a coarse grinder plate, such as a kidney plate, or by putting the meat through a dicing machine. This reduces the pieces of meat into chunks no larger than 1½ in. cubes. Salt, phosphate, and other seasoning ingredients are added at this point, and the meat is either mixed or tumbled to extract the myofibrillar proteins. Alternatively, a small amount of a meat emulsion or a non-meat binder may be added before mixing, which serves to bind the chunks of meat together.

Chunked and formed meat products may be cured or may be used fresh. Most of the cured products are classified as sausages since they are shaped by stuffing into casings and heat processed. Meat loaves, are also sausage products but are not stuffed into casings.

Fresh chunked and formed meat items typify restructured products; they are neither cured nor heat processed. They are shaped by either stuffing into casings or formed into meat logs. Contrary to popular opinion, however, the pressing operation does not facilitate meat bind-

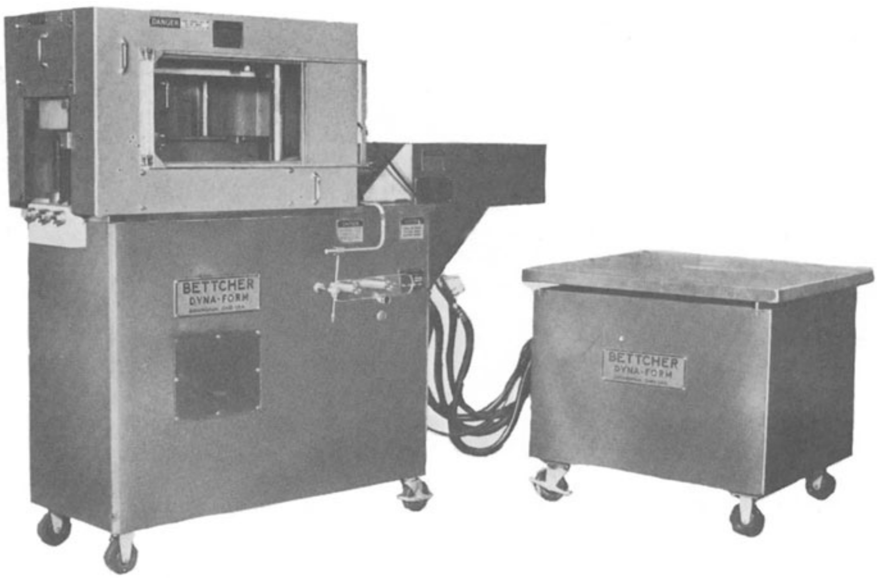

FIG. 15-1. A commercial meat press. Courtesy of Bettcher Industries, Inc. Vermillion, Ohio

ing. Figure 15.1 shows a meat press that is used to form the meat logs. After pressing and forming the logs should be frozen immediately. The logs must be tempered to facilitate slicing and are then sliced into the desired thickness using a power cleaver or slicer. Or, they may be formed into the desired shape by using commercial patty formers and then frozen and stored. Freezing and storage will be discussed later in this chapter, but is a most important step in maintaining the quality of the finished products.

Chunked and formed meat products have the advantage of maintaining more of the characteristic structure and texture of the original meat cuts. However, careful trimming to remove the sinews and excessive amounts of fat and other connective tissues is necessary to maintain quality in the finished product. In common with other restructured meats, care must be exercised in the mixing process to achieve the desired consistency. Too little mixing results in a loose texture and failure of the products to bind together. Too much mixing, on the other hand, results in rubbery products, which are tough and unacceptable.

A major disadvantage of chunked and formed fresh meats is their susceptibility to autoxidation, which is common to all restructured meats that are not cured using either nitrite or nitrate. Addition of antioxidants during processing will prevent oxidation, which causes fading of meat color and is accompanied by development of oxidized flavors. However, use of antioxidants in any restructured meat product requires prior approval by Federal Meat Inspection personnel.

Flaking and Forming

A number of precision meat slicing and flaking machines are available today that can be used to make thin slices or flakes of meat. Once the desired particle size and composition are attained, the meat is mixed with salt and phosphates until the product becomes moderately tacky. Mixing extracts some of the muscle proteins and makes the pieces adhere to each other. The flaked or sliced meat mixture is then stuffed under vacuum into suitable sized plastic bags, frozen and tempered. The tempered meat is then pressed or formed under pressure in a hydraulic meat press, which shapes and forms the products into the desired configuration. It can then be sliced into cuts of desired thickness. The flaked and formed products are packaged and held under freezer storage until they are thawed just prior to cooking.

Flaked and formed and sliced and formed meats are normally used only as fresh products, such as steaks, cutlets, chops, and roasts. The amount of salt added is generally between 0.5 and 1%, and sodium tripolyphosphate is added at a level of about 0.25%. These levels have been shown to be adequate for protein extraction and flavor development. Greater amounts of salt tend to make the products taste too salty; too much phosphate makes them rubbery in texture and gives the product a phosphate flavor. The sodium tripolyphosphate also chelates the non-heme iron, and thus delays development of rancidity. Since these products are not cured, nitrite and/or nitrate are not added to the meat.

Flaked and formed products have a texture similar, but not identical, to intact steaks, chops, or roasts. The texture is actually intermediate between that of ground meat and that of intact meat cuts. The flavor is also intermediate between that of intact meat cuts, such as roasts, chops and steaks, and that of ground meat. These factors make flaked and formed meats preferable to ground meat, and they are being developed and used by the Armed Forces as a means of decreasing subsistence costs. Flaked and formed meats are not only more economical than boneless intact meat cuts, but make use of lower priced cuts to produce higher value products. In addition, flaked and formed meats have a size and uniform shape that permits better portion control.

The chief disadvantages of flaked and formed meats are (1) greater labor requirements, (2) the cost of the equipment required, and (3) problems due to autoxidation. None of these disadvantages are unique to flaked and formed meats, but are problems inherent to producing all restructured meat products. Although the costs for specialized equipment and extra labor requirements are high, the advantages in upgrading of the final products into a higher value category may more than offset any additional costs. The problem of oxidation is more serious, but may be solved by eliminating contact with oxygen or air during processing and by adding antioxidants, as discussed in greater detail under chunking and forming in this chapter.

Tearing and Forming

As indicated earlier, attempts have been made to develop machines that tear the meat fibers apart, although machinery for this operation is not currently available. Nevertheless, the procedure has two advantages: (1) it would cause less membrane damage, and conceivably be less susceptible to oxidation, and (2) the product would have more structural integrity and more closely resemble intact meat cuts in texture. Although the second advantage is obvious, the difference in autoxidation rates may not be large enough to be important.

The mechanical problems associated with designing machinery suitable for tearing the meat fibers apart are difficult but are not insurmountable. The advantages of the process will no doubt stimulate further research on development of the process along with the necessary equipment.

RAW MATERIALS

All the precautions discussed in selection of raw materials covered in Chapter 6 apply to restructured meats. Only fresh meat that is microbiologically sound and free from flavor defects should be utilized in producing restructured meats. The muscle tissue should be boned just prior to utilizing or else made from freshly boned recently frozen meat. All sinews, tendons, glands, and excessive amounts of connective tissue and fat should be trimmed from the muscle tissue before subjecting it to restructuring operations.

Tenderization

If the meat to be restructured originates from anatomical locations or from mature animals that are believed to be tough, blade tenderization can be utilized to improve tenderness. Blade tenderization lends itself best to chunked and formed products made from coarsely ground or diced lean meats. Tenderization can best be accomplished on the large boneless cuts before they are ground and diced, although it can also be utilized for tenderizing previously chunked and formed meats. Blade tenderization is effective for tenderizing not only the white connective tissues surrounding the muscles, but will also tenderize the fatty tissue.

Size Reduction. Chunking, dicing, slicing, hydroflaking, flaking, and grinding are all procedures for reducing particle size. Larger muscles can be chunked manually, or passed through a coarse grinder plate or dicer for use in chunked and formed meats. The larger chunks can be used for making fresh oven roasts or else be used in cured meat products, i.e., especially in cured pork items. Chunking by passing through larger grinder plates (kidney plates) with or without the use of knives in the grinder gives irregular surfaces to the meat chunks. This technique increases the surface available for extraction of myosin and aids in better binding following mixing.

High speed equipment can be used for flaking and reforming of restructured meats. Tender cuts or muscles may be coarsely flaked, whereas, tougher cuts should be finely flaked to ensure tenderness of restructured products. On using frozen meats, low speed flaking reduces particle size without thawing of the meat.

Mixing

Mechanical agitation is necessary for disrupting the muscle fibers and releasing the muscle proteins. This step is essential for developing the sticky matrix on the surface of the chunks or flakes and is responsible for binding. Salt and polyphosphates aid in extraction of the myofibrillar proteins and should be added just prior to mixing. Vacuum mixing is preferred since it tends to eliminate oxygen and helps in delaying oxidation. Flushing with pure nitrogen gas also eliminates exposure to oxygen and aids in preventing oxidative changes in restructured meat products.

Maintenance of low temperatures during mixing not only helps in preventing oxidation but also assists in controlling microbial growth during the process. Thus, temperature control at all phases of the operations is critical in maintenance of the quality in restructured meat products.

Stuffing and Reforming

In producing most restructured products, the blended mixture is stuffed into casings or onto a tray for subsequent freezing. The mixture should be blast frozen at low temperatures, preferably in a range of 0° to −20°F. After freezing, the meat should be tempered for forming and slicing. The temperature necessary for these operations depends on the amount of salt and phosphate added. If the meat does not contain salt and phosphate, tempering to 26°–28°F is recommended. If 0.5% salt and 0.3% tripolyphosphate is added, the meat should be tempered at 22°–24°F. Meat containing 1% salt and 0.3% tripolyphosphate should be tempered at 20°–22°F. Thus, increasing the concentration of salt will permit tempering at lower temperatures.

The tempered meat is pressed into the desired shape using a hydraulic meat press. Continuous vacuum stuffers may be utilized to extrude meat logs that are frozen, tempered, and sliced into the desired sized portions. New and improved types of equipment are constantly being produced to facilitate forming and slicing. It is probable that new developments in this area will completely revolutionize the production of restructured meats within the next few years.

Influence of Raw Materials on Selection of Processing Procedures

The type of raw materials and their inherent quality will determine to a large extent the type of equipment used for reduction of particle size prior to subsequent reforming or restructuring. For example, if rib caps and steak trimmings from USDA Good grade carcasses or better are to be utilized for producing restructured steaks, they should be coarsely flaked. This will give a texture resembling that of an intact steak. A schematic flow diagram for producing this product is shown in Fig. 15.2, but does not give detailed instructions for manufacturing.

Lower quality raw materials may require a different procedure. For example, Fig. 15.3 is a flow diagram for using the rib cap and chuck clod from USDA Good grade cuts or higher, which are relatively tender, and the chuck, plate, steak tail, and lean trimmings, which are tougher cuts. In this case, the tender cuts (rib cap and chuck clod) are coarsely flaked and the tougher cuts (chuck, plate, steak tail, and trimmings) are finely flaked and then mixed together.

Figure 15.4 is another flow diagram in which USDA Standard or Utility grade beef rounds or chucks are used in combination with

Beef (22°–32°F)
[Rib cap / Steak trimming]
↓
Coarse Flake
↓
Formulate 13–15% fat
↓ Dissolve 0.5% salt and 0.5% tripolyphosphate in water
Vacuum mix
↓
Extrude
↓
Wrap in film
↓
Freeze
↓
Temper
↓
Mold
↓
Slice
↓
Vacuum package

FIG. 15-2. Method of processing USDA good grade or better restructured products. From Committee on Animal Products (1982).

USDA Prime, Choice, or Good grade beef plates. The lower grade rounds are blade tenderized prior to coarse grinding, whereas the higher grading beef plates or chucks are thinly sliced. This reduces the connective tissue to smaller particles and slices the fatty tissues into thin flakes so it can be distributed throughout the lean during mixing to resemble marbling.

These three flow charts (Figs. 15.2, 15.3, and 15.4) illustrate how the processing procedures can be altered to produce products of acceptable tenderness from cuts differing in inherent quality. The tougher cuts require reduction into smaller sized particles or blade tenderization prior to size reduction, whereas tender cuts require less reduction in particle size for maintaining the structural characteristics associated with intact meat cuts.

Table 15.1 gives the approximate fat content of some beef cuts that are used frequently for preparing restructured meats. Although these values are only guides, they do give information that may be useful for planning the composition and type of processing that is necessary for producing restructured meats.

Desinewing

Mechanically desinewed meat can be produced from cuts that are high in connective tissue. Yields for the desinewed meat are variable

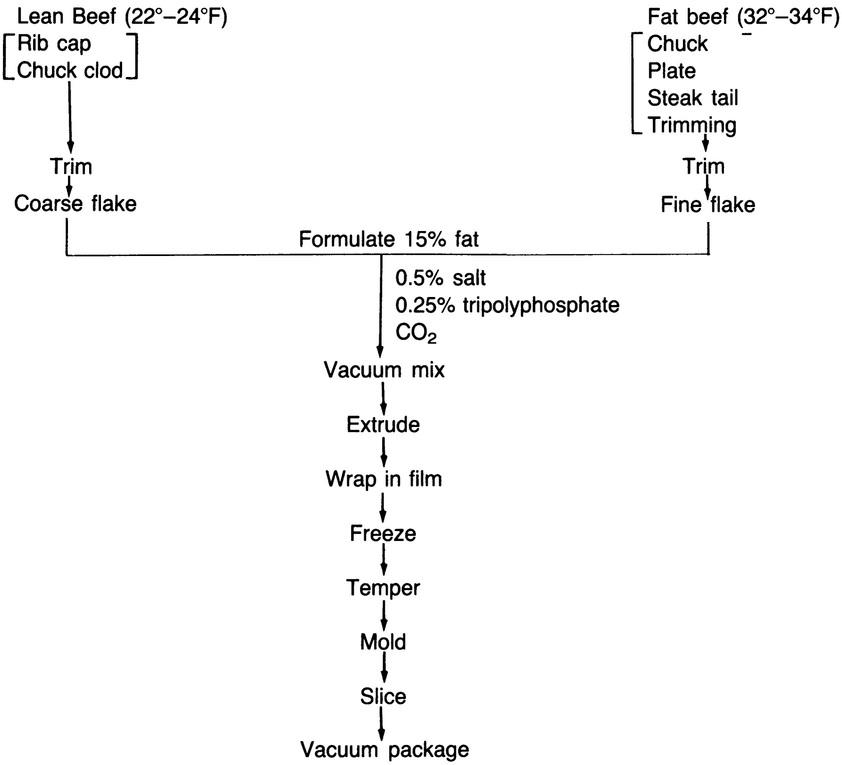

FIG. 15-3. Method for processing mixture of high and low quality beef into restructured products. From Committee on Animal Products (1982).

and depend on the relative amounts of connective tissue in the raw cuts. Yields are approximately 71% for beef plates, 81% for beef shanks, 86% for beef chucks, and 87% for pork shoulders. The desinewed meat produces products that are more tender and have an improved texture. They also have less tendency towards gelatin formation during subsequent cooking. The process is most effective on meat from old animals, and in cuts having a high connective tissue content. Desinewing removes about 50% of the total connective tissue content of the meat.

The usefulness of desinewing the cheaper meat cuts for use in restructured meats is obvious. However, the greater costs for equipment and labor must be balanced against the upgrading of the cheaper cuts into higher value products. Complete mechanization of the processes will aid in making it more feasible.

Mechanically Deboned Meat

From 5 to 20% of mechanically deboned meat can be utilized in restructured meat products. Up to 10% of mechanically deboned meat

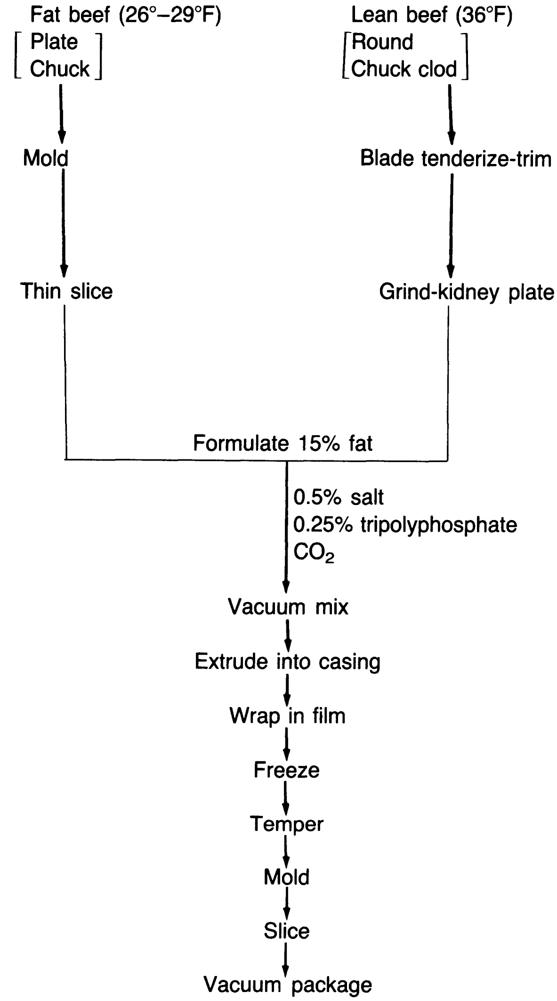

FIG. 15-4. Method of processing mixture of USDA standard or utility grade beef rounds and USDA good, choice, or prime grade beef plates into restructured products. From Commttee on Animal Products (1982).

in restructured steaks not only reduces the cost but improves the texture. Use of more than 20% of mechanically deboned meat in restructured products is not advisable, since the flavor and texture are adversely affected.

Freezing and Storage

Although freshly frozen meat may be used as raw material, it should show no evidence of oxidation or freezer deterioration. It should be utilized for processing within 90 days of freezing, since longer storage periods will appreciably shorten the freezer shelf-life of the restruc-

TABLE 15.1. Approximate Fat Content of Some Beef Cuts That May Be Utilized in Preparation of Restructured Meat

Cut (beef)	Percentage fat
Rib cap	7.0
Chuck clod	10.0
Round	10.0
Imported frozen boneless beef	10.0
Steak-tail	17.5
Chuck (Three-way boneless)	25.0
Boneless plate	50.0
Trimmings (50% lean)	50.0

tured products. Any evidence of deterioration in quality should result in rejection of meat for use in restructured meat products, since frozen meats do not improve during frozen storage.

Good temperature control, both during freezing and subsequent freezer storage, is essential for maintenance of meat quality. Freezing should always be as rapid as possible to control microbial growth, to slow down oxidative changes, and to inhibit enzymatic activity. Rapid freezing can best be attained by a combination of low temperatures and rapid air movement or blast freezing. Temperatures for freezing should be at least 0°F or below with rapid air movement across the product in order to reduce the temperature in the interior of the products quickly.

Equally important with rapid frezing is maintenance of low product temperatures during freezer storage. A storage temperature around 0°F, and no higher than 10°F, is recommended. Fluctuations in freezer storage temperatures and during transportation are equally as damaging as high storage temperatures, and should be avoided as much as possible. Freezer storage temperatures should not only be carefully controlled, but the duration of freezer storage should be limited in order to maintain quality.

Packaging of restructured meats to prevent freezer burn (dehydration) and oxidation is most important. The products should be carefully wrapped in good quality freezer paper, exercising caution to bring the restructured product into close contact with the film in order to prevent cavity ice formation. Polyethylene film or other films suitable for freezing are satisfactory. Packing of larger quantities of the restructured products should be in wax-impregnated fiber board boxes of sufficient strength to withstand the shock of handling during transportation to the market.

Tempering of the meat before size reduction and reforming into the desired shape is necessary. This can be done by holding the previously frozen meat at a temperature between 26° and 28°F for at least 24 hr. Temperatures above freezing can also be used for tempering and will require less time, but high temperature tempering should never be carried out above 40°F. Tempering tunnels equipped with microwaves are also being used, and have the advantage of tempering without any drip losses. Once the tempering operations are completed and the meat is packaged, it should be returned to low temperature storage.

The factors concerning freezing and freezer storage apply to both raw materials and to manufactured restructured meats and should be applied to handling of restructured meats throughout manufacturing and subsequent freezing and freezer storage.

RESTRUCTURED MEAT FORMULATIONS

Procedures for formulating restructured meats are given with flow diagrams and details on the methods as available. The cuts given for formulation have been successfully incorporated into the products described. This does not imply that other cuts and processing procedures cannot be used successfully. In some instances, certain pieces of equipment used in the process are identified by trade name and even by model numbers. The inclusion of this information does not constitute endorsement of the particular item of equipment to the exclusion of others, but merely indicates that the machine mentioned by name has been utilized successfully. Obviously, new developments and inventions will result in more advanced equipment that may completely replace the items that are currently used.

Raw materials will be discussed first, followed by the processing methods, which in some instances will be shown by flow charts. Special precautions and possible alterations and notes will be used to explain how the products are formulated. A reasonable amount of development work has been carried out on all the restructured meat products described herein, with some of them being routinely produced with success. Others included have been produced experimentally and are believed to show promise for producing marketable restructured items.

Flaked and Formed Beef Steaks

Raw Materials. Flaked and formed steaks are manufactured from beef derived from steer, heifer or cow carcasses, or quarters or their recognizable primal cuts (square cut chucks, ribs, loins, or rounds) of the specified USDA carcass grades. The lean tissues and fatty tisues should be in excellent condition with no evidence of microbial activity, oxidation, or discoloration. The beef should be completely boned and carefully trimmed to remove sinews, glands, excess connective tissue and fatty tissue.

Salt should be white refined sodium chloride with or without anti-caking agents as permitted under federal meat regulations, and sodium tripolyphosphate must be of food grade as specified in the Federal Meat Inspection regulations.

Processing. The meat is processed as shown in Fig. 15.5, using USDA Choice grade square cut beef chucks. The boneless trimmed meat is flaked once with an Urschel Comitrol Comminutor Model 2100 equipped with a 3J030750 or 3J060750 head or an equivalent flaking device. The temperature during flaking should not be allowed to exceed 42°F. Dry ice may be added at any time during processing to keep the temperature of the flaked meat at 40°F or below.

The flaked meat is mixed with 0.5% salt and 0.3% sodium tripolyphosphate by weight in a vacuum mixer. Mixing is continued until the mixture is uniform in appearance and becomes moderately sticky.

The mixture is mechanically stuffed under vacuum into suitable plastic bags. The meat is frozen and then tempered at 22°–24°F. The tempered meat is then pressed or formed into the desired shape (Fig. 15.6) using a hydraulic meat press at not less than 500 psi (3447 kPa). The formed product is then sliced into uniform steaks. The preferred

Fresh-chilled square cut chuck (Choice grade) (Bone-in)	40°–45°F
↓	
Boning–Trimming	40°–45°F
↓	
Flaking (Urschel Comitrol No. 3600)	35°–40°F
↓	
Mixing 0.5% NaCl 0.25% Sodium tripolyphosphate	40°–42°F
↓	
Vacuum stuffing into casings (Permeable Polyethylene)	40°–45°F
↓	
Freezing of meat logs	0°F
↓	
Tempering of meat logs	26°–28°F
↓	
Pressing of meat logs (Bettcher Press No. 70, 2,500 psi)	
↓	
Slicing of meat logs (Bettcher Cleaver No. 39)	
↓	
Packaging and storage	0°F

FIG. 15-5. Outline of the flaking process for producing restructured beef steaks. From Committee on Food Stability (1982).

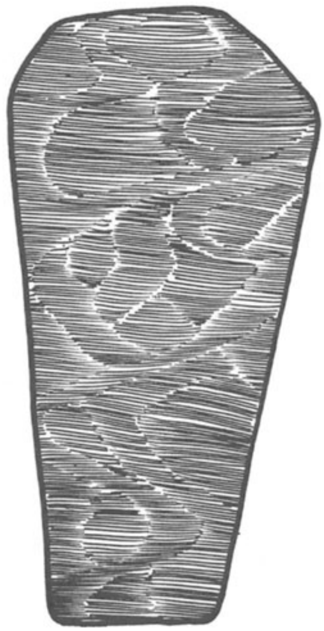

FIG. 15-6. Diagram showing shape and size of flaked and formed beef steak. Steak shown is half actual size.

weight and thickness may be varied according to demand. U.S. Army Natick Research and Development Command purchase descriptions specify that steaks should weigh no more than 6.5 oz or no less than 5.5 oz and be no more than 0.9 in. and not less than 0.5 in. thick.

If production of flaked and formed beef steaks are under U.S. Army contract, the sampling, techniques and compositional requirements are clearly spelled out. The average acceptable fat content of the sample must be between 12.0 and 22.0%, but samples having a fat content between 12.00 and 13.99% on the low end and between 20.01 and 22.00% on the high end are discounted on a percentage of contract price. This basically indicates that the samples must fall within an average fat content of 14.0–20.0%.

Flaked, Formed, and Diced Beef Steak

Raw Materials. Flaked, formed, and diced beef steaks are prepared from carcasses, quarters, or recognizable wholesale or subprimal cuts from steers, heifers or cows of the specified USDA quality grade. The cuts that can be used include square cut chucks, ribs, trimmed full loins, trimmed shortloins, loin ends, striploins, rounds, shoulder clods, chuck rolls, ribeyes, top rounds, knuckles and bottom rounds. Both fat and lean tissues should be in excellent condition, with no evidence of oxidation, discoloration, or bacterial activity. After being selected and approved, the meat should be completely boned and carefully trimmed to remove any dissectable sinews, glands, and excessive amounts of connective tissue and fat.

Salt should be refined white sodium chloride with or without added anti-caking agents as permitted under Federal Meat Inspection Regulations. Sodium tripolyphosphate should also be of food grade as outlined in the Federal Meat Inspection Regulations.

Processing. The boneless and trimmed meat is flaked once through an Urschel Comitrol Model 2100 Comminutor equipped with a 3J030750 or 3J060750 head. The temperature of the meat should not be allowed to exceed 42°F at any time and should not exceed a temperature of 40°F immediately following flaking. Dry ice is added as needed to maintain the low temperatures.

The flaked meat is mixed with 0.5% salt and 0.3% sodium tripolyphosphate by weight in a mechanical mixer. Mixing is continued until the mixture is uniform in appearance and becomes moderately sticky. The mixture is then stuffed into suitable plastic containers and frozen at once.

The product is then tempered to 22°–24°F, and formed into a rectangular block using a hydraulic meat press at 500 psi. The block of meat is then passed through a mechanical dicer to produce cubes of the desired size. The diced steaks are immediately packaged and frozen at a temperature of 0°F or below.

Precautions. The composition requirements for fat are the same as for flaked and frozen beef steaks. It is important to have good temperature control at all stages of the process and to complete all processing as quickly as possible.

Flaked and Formed Breaded Veal Steaks

Raw Materials. Veal and/or calf are the only acceptable meat ingredient(s). The meat may be derived from any combination of carcasses, quarters, and/or recognizable primal cuts (square cut shoulders, racks, loins, or legs) that qualify as USDA Standard grade or higher. All of the meat should be in excellent condition as indicated by the color of the lean surfaces, lack of evidence of microbial activity, or signs of oxidation. The meat should be boned and carefully trimmed to remove any sinews, glands, and excessive amounts of fat and/or connective tissue.

All materials used for breading should be commercially prepared coating mixtures without any artificial coloring. They shall be specified as meeting the requirements for this type product according to the label of the manufacturer.

Processing. The temperature of the meat should never exceed 42°F during flaking. Dry ice may be added to maintain the temperature of the flaked meat at 40°F or below. The temperature of the batter during breading should not exceed 50°F. The boneless meat is flaked through an Urschel Comitrol Comminutor Model 2100 equipped with a 3J030750 or 3J060750 head or an equivalent flaking device.

After flaking, the meat is mechanically mixed until it becomes moderately sticky. The mixture is stuffed under vacuum into suitable plastic bags and frozen. The frozen mixture is next tempered to 26°–28°F and then pressed into meat logs of the desired shape at a pressure of 550 psi using a hydraulic meat press. The formed logs are then sliced into steaks of the shape shown in Fig. 15.7.

The steaks are made to desired weight and thickness to meet market demands. U.S. Army procurement specifications specify the steaks should not weigh more than 6 oz or less than 5 oz, with a maximum thickness of 0.4 in. and a minimum thickness of 0.6 in. before breading.

Coating. All breading and batter shall be applied by a mechanical breading machine. The combined breading and batter should not exceed 30% by weight of the finished veal steaks.

Precautions. Care should be taken to process rapidly and to freeze immediately. If the product is prepared under U.S. Army contract, the method of packaging. specifications on the breading procedure and other requirements are stated clearly.

Flaked and Formed Breaded Pork Steaks

Materials. Pork should be the only meat ingredient and should come from any one or a combination of the following recognizable wholesale cuts: shoulders, shoulder picnics, Boston butts, hams, and loins. Preferably the meat should be processed within 5 days of slaughter. Regardless, the meat should be in excellent condition with no evidence of bacterial activity, discoloration of lean or fat or any other

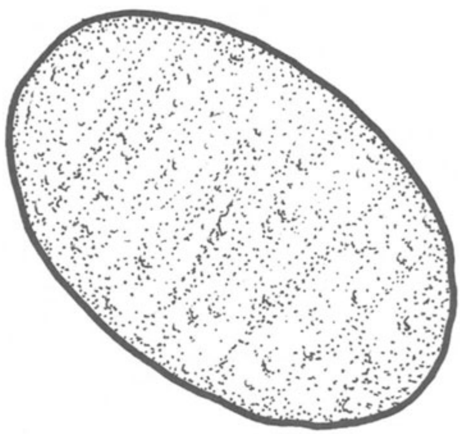

FIG. 15-7. Flaked and formed veal steak after breading, showing size and shape. Steak shown is half the actual size.

defects. Pale, soft, and exudative (PSE) and dark, firm, and dry (DFD) meat should be avoided. Coarse textured meat and pork with sex odor and other off odors should not be used.

Only commercially prepared coating ingredients of known composition and without added coloring should be used.

Processing. The boneless trimmed meat is flake-cut through an Urschel Comitrol Comminutor Model 2100 equipped with a size 3J030750 or 3J060750 head or an equivalent flake cutting device. The temperature of the meat should not exceed 42°F at any stage of processing, and the temperature of the meat immediately following flaking should not exceed 40°F. Low temperatures can be maintained by adding dry ice if needed.

The flaked product is mixed in a mechanical mixer until it appears to be uniform in composition and is moderately sticky. The flake-cut mixture is then stuffed into suitable plastic bags and frozen at 0°F or below in a blast freezer.

The frozen mixture is tempered to 26°–28°F and pressed into meat logs in a hydraulic meat press at not less than 500 psi. The meat logs are then sliced into steaks of not less than 0.4 in. nor more than 0.6 in. thick and should weigh not less than 5 nor more than 6 oz after coating. Figure 15.8 shows the shape and size of the flaked and formed, breaded pork steaks.

Coating. The breading and coating should not exceed a temperature of 50°F at the time of application. The coating and batter should be applied with a breading machine. Any unused breading or batter should be discarded at the end of each day's operation.

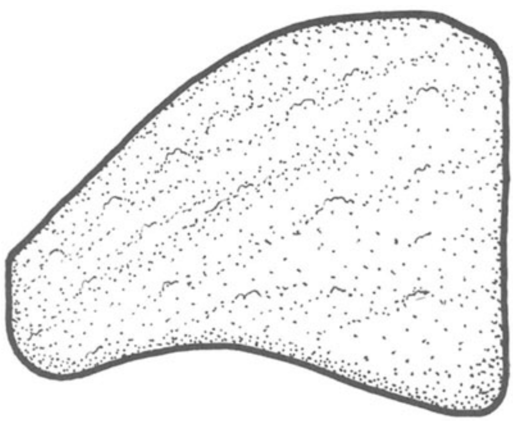

FIG. 15-8. Diagram of flaked and formed breaded pork steak showing size and form. Steak shown is half the actual size.

Precautions. Care should be exercised to see that the temperature recommendations are strictly adherred to in all phases of the operation. The operations of flaking, mixing, stuffing, bagging, and placing in the freezer should be completed in one working day. The tempered meat should also be press-formed, sliced, coated, packaged, packed, and placed in the freezer during a single working day.

The final fat content of the breaded steaks should average from 18 to 22%, with values above 20% being less desirable. U.S. Army Natick Laboratory specifications give a discount schedule for products over 20.00% fat and reject samples above 22% fat.

Flaked and Formed Diced Pork

Materials. Pork is the only meat ingredient and comes from selected wholesale cuts, including shoulders, shoulder picnics, Boston butts, hams, and loins. The same high quality standards are necessary as for flaked and formed breaded pork steaks.

The meat should be carefully boned and all tendons, glands, and excess fat removed. Preferably the meat should be processed within 5 days of slaughter, and there should be no evidence of discoloration or bacterial activity on either the lean or fat. PSE or DFD meat or meat with sex odor or other defects should not be utilized.

Processing. The boned and trimmed pork meat is flake-cut once through an Urschel Comitrol Model 2100 Comminutor using either a 3J030750 or 3J060750 head or an equivalent cutting device. The meat should be at a temperature of no more than 40°F immediately after flaking, and should not be allowed to exceed 42°F at any time during processing. Dry ice may be added if necessary to maintain low temperatures.

After flaking, the meat is placed in a mechanical mixer and mixed until uniform in appearance and moderately sticky. Once the desired consistency is achieved, the flaked meat is mechanically stuffed into suitable plastic bags and frozen at 0°F in an air blast freezer.

The frozen flaked meat is then tempered to 26°–28°F and pressed into rectangular blocks at a minimum of 500 psi using a hydraulic meat press. The block is then diced into the desired size cubes on a power meat dicer. The diced meat is then packaged and blast frozen at 0°F.

Precautions. Careful temperature control should be exercised at all times. The fat content should be from 18.00 to 22.00%, with 18.00 to 20.00% being preferred. U.S. Army specifications discount those lots having a fat content from 20.00 to 22.00%, and reject those above 22.00% fat.

Flaked and Formed Lamb Steaks

Materials. Lamb is the only meat ingredient allowed in flaked and formed lamb steaks. It should come from any combination of carcasses, quarters, and/or recognizable wholesale cuts, including square cut shoulders, racks, loins, and legs. USDA quality grade Good or above. Both the lean and fat should be in excellent condition, showing no signs of bacterial activity, loss of color in either the lean or fat, or any other unsoundness.

The meat should be boned, removing all sinews and coarse connective tissue deposits. Excess amounts of fat and any glands should also be removed.

Processing. The boneless meat is flaked by passing it through an Urschel Comitrol Comminutor Model 2100 using a size 3J030750 or 3J060750 head or some other equivalent flaking device. The temperature of the flaked meat should not exceed 40°F immediately after flaking, and should not be allowed to exceed a temperature of 42°F at any stage of processing.

The flaked meat is placed in a mechanical mixer and mixed until uniform in appearance and moderately sticky. The mixture is then stuffed into casings using a vacuum stuffer, after which it is frozen at 0°F in a blast freezer.

The frozen flaked meat is tempered to 26°–28°F and then formed into the desired shape using a hydraulic meat press at a pressure of at least 500 psi. The shape and size of the meat logs is shown in Fig. 15.9. The logs are then cut into steaks weighing between 4.5 and 5.5 oz using a power frozen meat slicer. The thickness of the steaks should be between 0.6 and 0.9 in. The steaks should be immediately refrozen at 0°F in a blast freezer, packaged, and boxed. The fat content of the steaks

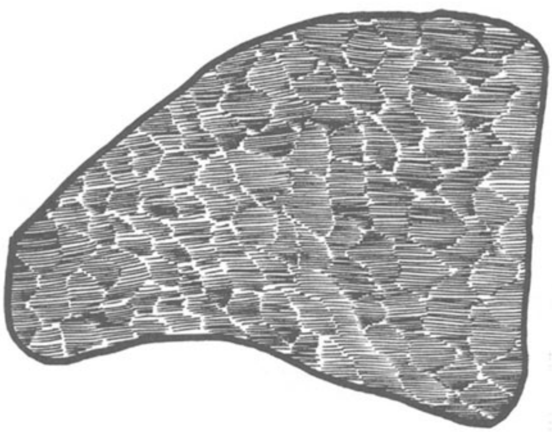

FIG. 15-9. Diagram showing the shape and size of flaked and formed lamb steak. Steak shown is half the actual size.

should be from 16.0 to 20.0%, with U.S. Army contracts specifying a discount in price between a fat content of 18.00 to 20.00%

Precautions. As with all other flaked and formed meat products temperature control is of the utmost importance at all stages of processing. The flaking, mixing, stuffing, and freezing operations should be accomplished in a single working day. Similarly, the frozen and tempered meat should be pressed, shaped, sectioned, packaged, and frozen in one working day.

Restructured Pork Roasts

Raw Materials. Pork should be the only meat ingredient used for preparing restructured pork roasts. The following recognizable wholesale cuts alone or in combination together can be used: shoulders, shoulder picnics, Boston butts, hams, and loins. If shoulders or shoulder picnics are used as the sole source of pork, the product will be tough because of the high connective tissue content of the shank meat. Preferably the meat should be processed within 5 days of slaughter. The meat should be selected to that the blended product contains about 16.0–18.0% of fat by analysis and not over 20.0%. It should show no evidence of bacterial activity nor any discoloration of the lean or fat. PSE or DFD pork should be avoided. Coarse-textured pork or meat with sex odor and other off odors should not be used.

The added salt should be refined white sodium chloride with or without anti-caking agents as permitted by Federal Meat Inspection Regulations. Sodium tripolyphosphate should be of food grade as also detailed in the Federal Meat Inspection Regulations.

Processing. The pork cuts are carefully boned, removing any sinews, glands, or unsound portions. The fatty and lean tissues are roughly separated into their respective fractions and chilled rapidly.

The chilled lean tissues are passed through a meat grinder equipped with a three-hole kidney plate and a special knife with two half-length arms, as shown in Fig. 15.10. The lean meat is added to a vacuum mixer along with 0.25% tripolyphosphate and 0.90% salt and blended together until uniform in appearance and it begins to feel slightly sticky. In the meantime, the thoroughly chilled fatty tissues are ground through a ⅛-in. grinder plate and kept cold. The ground fatty tissues are added to the lean meat mixture and blended together until discrete fatty particles are no longer evident.

The meat mixture is stuffed into polyethylene bags or No. 4 fibrous casings and formed into an oval shape using a spring-loaded ham mold. If the meat is stuffed into No. 4 fibrous casings, each roast is vacuum packed in a polyethylene bag. This will protect the roasts from freezer burn and materially extend their freezer storage life. The roasts, which weigh approximately 4 lb each, are blast frozen at 0°F or lower. The

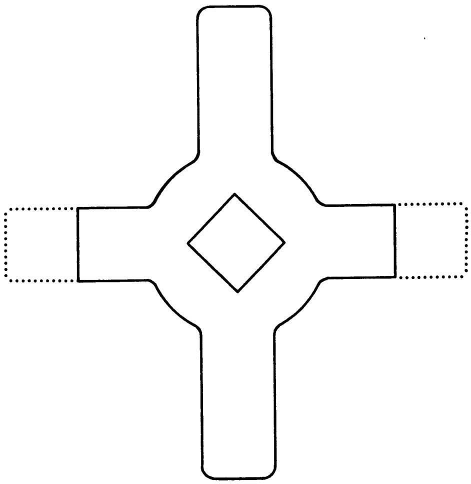

FIG. 15-10. Diagram of special knife for meat grinder with two half-length arms. Dotted lines show the portions of the arms that were removed.

restructured frozen roasts are packed into polyethylene lined boxes for shipping.

Precautions. Care should be exercised to maintain the temperature of the meat below 42°F at all times. If the temperature increases above 40°F during grinding and/or mixing, dry ice may be added to lower it. Careful temperature control is important not only during processing, but also during subsequent storage and marketing.

Restructured Beef Roasts

Materials. The only meat ingredient should be beef using wholesale square cut chucks and rounds of USDA Commercial grade or higher. The meat should be free of any evidence of bacterial activity and any discoloration of the lean and fat.

The salt utilized for processing should be refined white sodium chloride with or without anti-caking agents as outlined in the Federal Meat Inspection Regulations. Sodium tripolyphosphate should be food grade and also comply with Meat Inspection requirements.

Processing. The meat is carefully boned to remove all sinews, glands, and excessive amounts of dissectable connective tissues. The square cut chucks are defatted to contain 13–15% fat or have 85–87% lean meat. After defatting, the chuck meat is passed through a dicer set to make 1½- to 2-in. chunks. The boneless rounds should have a fat content of 7–9% or contain 91–93% lean. The rounds are put through an Urschel Comitrol Comminutor Model 2100 equipped with a 270 mm series K head (3-K-030270D) or an equivalent flaking device.

The final product should contain 5–20% of the flaked round, 75–90%

of diced chuck meat, 3–4% of added cold water, 1% of salt, and 0.25% sodium tripolyphosphate. First, the flaked round meat is added to a vacuum mixer along with the salt and sodium tripolyphosphate. After thoroughly blending together, which requires about 5 min, the water is added and mixed until the meat is slightly sticky and of a uniform consistency (approximately 5 more min). Then the diced chuck meat is added and blended until the entire mass is moderately sticky and holds together (approximately 15 min more). The mixing times are only rough guides since the speed of mixing and the properties of the blend are the final determinant at each stage of mixing.

The meat mixture then is stuffed into 7 × 28 in. clear fibrous casings using a vacuum stuffer. The stuffed fibrous casings are vacuum packed in appropriate sized polyethylene bags in order to protect them from moisture losses during cooking and/or freezing. The stuffed roasts are either frozen by air blast at 0°F, or they may be cooked and then frozen.

If the roasts are to be cooked, they are placed in an oven or smokehouse at 200°F and 70% relative humidity with convection heating until the meat reaches an internal temperature of 150°F, which requires approximately 4 hr. Remove from the oven and cool. If a lighter colored cooked roast without surface browning is desired, the relative humidity during cooking can be increased to over 90%.

The product should be air blast frozen at 0°F or lower and packed two to a 18 × 10 × 4¾-inch box (No. 10 steak boxes), which is lined with polyethylene.

Precautions. The importance of temperature control is emphasized, both during processing and freezer storage. The same precautions for maintaining low temperatures during freezing and freezing storage apply as is the case for other restructured meat products.

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16

Analytical Methods

Most of the analytical procedures detailed in this chapter yield excellent results when used by technicians under general supervision. Some of the methods are modifications of those of the Association of Official Agricultural Chemists. They are especially suited where accurate, reliable methods for analyzing raw materials, emulsions, and finished products are needed.

The proximate analysis uses a 30-g sample. This one sample is used to analyze for moisture, protein, fat, and ash. With this method, the variation in composition of single frankfurters can be determined. The sample is dried by heat for moisture, and the dried residue is extracted with a fat solvent for fat content. The solvent is removed by heating and the fat residue is weighed. The fat-free residue (FFR) is also weighed, and this acts as a check on the fat content by difference. The FFR is split into aliquots for protein analysis by the Kjeldahl method. An aliquot sample is used for ash by incinerating and weighing the ash residue. The ash-plus-protein in an all-meat product is equal to the FFR weight. An FFR greater than the ash plus-protein indicates the presence of carbohydrate materials and is suggestive of non-meat additives such as milk products or vegetable residues.

Rapid methods which sacrifice some accuracy are commonly used today in processed-meat operations to determine the fat, moisture, and protein content of raw materials at various stages of processing and in the finished products. Knowledge of the content provides a reasonable means of control, and many methods for rapid fat analysis have been devised including rendering and weighing, volumetric measurement, specific gravity, X-ray, dielectric measurements, or ultrasonic waves. However, only the standard analytical methods are accepted as legally valid. These methods are discussed in some detail along with some of the rapid methods of analysis that are being used by the industry today.

MOISTURE

Theory

Determination of moisture is made by drying the sample at elevated temperatures. Percent moisture is derived from the difference in weight of the sample before and after drying.

Apparatus

Analytical balance
Drying oven
Aluminum cans with covers, 2½ in. diameter, 3¾ in. deep
Desiccator
Laboratory grinder, chopper, or blender

Procedure

Select a representative product sample. If not already finely comminuted, grind, chop, or comminute in a blender until finely divided and uniform in composition. Weight exactly 30.0 g of the chopped sample into a previously weighed aluminum can. Dry in an oven at 212°F to a constant weight (about 12 to 16 hr). Cover the can and allow to cool in a desiccator before weighing.

Calculation of Results

weight of solids = weight of dried sample and container − weight of container

$$\% \text{ solids} = \frac{\text{weight of solids}}{\text{weight of original sample (30.0 g)}} \times 100$$

$$\% \text{ moisture} = 100.00 - \% \text{ solids}$$

Test Limitation

The method depends on the volatilization and subsequent evaporation of water from the sample. The meat sample may contain substances other than water that are volatile at 212°F.

FAT

Theory

Determination of the fat content of the moisture-free sample is done by extracting the fat with a suitable solvent.

Apparatus

Spatula
Soxhlet apparatus with heat-controlled unit
Drying oven
Glass funnel
Analytical balance

Reagents

250 ml Skellysolve F (technical grade solvent, hexane or petroleum ether) (Skelly Petroleum Products Co.).

Procedure

Carefully transfer the moisture-free sample to an extraction thimble. Small particles of solids and separated fat in the aluminum can are removed by repeated washing with the solvent. Place extraction thimble in the extractor with an attached receiving flask and pour the solvent washings into the thimble through a glass funnel. Connect the extractor and receiving flask to the Soxhlet condenser. Adjust the electrical heating unit so the solvent syphons over 5 to 6 times per hour and extract the fat on the Soxhlet apparatus for 16–20 hr. Remove the extraction thimble and place it in the original aluminum can. Evaporate the remaining trace solvent from the fat-free residue by drying in the 212°F oven (about 2 hr). With the aid of a spatula, carefully transfer all residue from the thimble to the aluminum can. Weigh the can containing the fat-free residue.

Calculation of Results

weight of fat-free residue = weight of fat-free residue and container − weight of container

$$\%\ \text{fat-free residue} = \frac{\text{weight of fat-free residue}}{\text{weight of original sample (30.0 g)}} \times 100$$

weight of fat = weight of moisture-free solids and container − weight of fat-free residue and container

$$\%\ \text{fat} = \frac{\text{weight of fat}}{\text{weight of original sample (30.0 g)}} \times 100$$

Test Limitation

Skellysolve F (hexane), in addition to the fat, may, on rare occasions, extract other materials present in the sample.

Safety Precaution

Skellysolve F (hexane) is flammable. Use adequate ventilation and avoid open flames.

PROTEIN

Theory

Determination of protein in a meat sample is done by measuring total nitrogen in the sample by the standard Kjeldahl method and converting this value to percent protein.

Apparatus

Kjeldahl digesting apparatus
Kjeldahl distilling apparatus
2 800 ml Kjeldahl flasks
1 100 ml graduate cylinder
2 500 ml Erlenmeyer flasks
1 50 ml burette
Analytical balance
2 pieces of tared nitrogen-free filter paper
4 glass beads

Reagents

Copper wire (No. 18 gauge, 3 in. length)
35 ml sulfuric acid
15 g potassium sulfate (granulated A.R. ACS Standard)
400 ml distilled water
60 ml 50% sodium hydroxide
50 ml 2% boric acid
5 parts alcoholic 0.1% bromcresol green
1 part alcoholic 0.1% methyl red
4 g mossy zinc (C.P., ACS Standard)
0.5 *N* hydrochloric acid

Procedure

Prepare the sample by grinding the fat-free residue (see analysis of fat). Weigh an aliquot of sample on a piece of tared nitrogen-free filter paper. Carefully fold the filter paper containing the sample and transfer to a Kjeldahl flask. Add a piece of copper wire, 35 ml sulfuric acid, 2 glass beads, and 15 g potassium sulfate. Heat the mixture gently on the digestion apparatus until frothing ceases. Boil briskly, and continue the digestion for a time after the mixture is colorless (about 2 hr). Cool the flask. Slowly add 400 ml distilled water and 60 ml 50% sodium hydroxide. Pour the sodium hydroxide solution down the side of the flask so that it does not mix at once with the digest. Add a chunk of the mossy zinc to the flask. Transfer the Kjeldahl flask to the distilling apparatus and connect it to the condenser by means of the Kjeldahl connecting bulb. Place the condenser tip in a 500-ml Erlenmeyer receiving flask containing 50 ml 2.0% boric acid solution. Mix the contents by shaking; heat gently, and distill 150–200 ml of distillate into the receiving flask. Break contact of the condenser tip with the distillate and continue distillation 2 to 5 min to steam out the condenser.

Titrate the distillate with standardized 0.5 *N* hydrochloric acid. The end point is reached when the distillate color changes from blue-green to colorless.

Calculation of Results

$$\% \text{ protein} = \frac{\text{ml hydrochloric acid} \times \text{normality} \times 0.014 \times 6.25 \times 100}{\text{weight of aliquot sample}}$$

If numerous Kjeldahl determinations are to be made, a practical modification is an adjustment of the normality of the standardized hydrochloric acid to 0.57143 N. The protein factor (normality × 0.014 × 6.25) is then 0.0500. If the weight of the sample aliquot is calculated at $\frac{1}{10}$ of the percent of fat-free residue, percent protein is calculated by dividing the milliliters of titer by 2.

Test Limitation

It is assumed that all the nitrogen is found in the proteins and that the nitrogen content of the protein is 16%. Therefore, a factor of 6.25 is used.

Safety Precautions

Kjeldahl digestion should be carried on under a fumeless hood. Exercise care when handling strong acids. Wear safety glasses.

ASH

Theory

Organic material is removed by heating and the remaining inorganic salts are determined gravimetrically.

Apparatus

Muffle furnace
Analytical balance
2 tared porcelain crucibles (30-ml)
Pair crucible tongs
Spatula

Procedure

Weigh an aliquot of fat-free residue into a porcelain crucible. Place the crucible in a muffle furnace not exceeding 500°C for 12 hr. Cool in a desiccator. Then weigh ash and crucible.

Calculation of Results

$$\text{weight of ash} = \text{weight of ash and crucible} - \text{weight of crucible}$$

$$\%\ \text{ash} = \frac{\text{weight of ash}}{\text{weight of sample}} \times 100$$

Test Limitation

Ash content depends to a degree on the nature of the ash. Certain constituents (chlorides) may be volatilized, reduced (sulfates), or distilled as complexes during the early stages of ashing.

NITRATE

The determination of nitrate in biological materials such as meat or cheese is complex and, while several methods are available, the method and procedures of the Lancaster Laboratories[1] have proved to be adequate for determining nitrates in fermented sausages.

Theory

Nitrate is reduced to nitrite and the nitrite is determined by measuring spectrophotometrically the color formed by the reaction with a coupling reagent. When samples contain both nitrite and nitrate, the nitrite content is first determined from the unreduced sample filtrate, and the total nitrite content (existing nitrite and nitrite formed from nitrate) from the reduction column eluate. The nitrate content is then calculated by difference.

Apparatus

Wrist action shaker
Spectrophotometer
Reduction column

Prepare a supply of metallic cadmium by placing zinc rods into 500 ml of 20% $CdSO_4$ solution. After reaction of approximately 3 hrs, discard solution and scrape moss-like Cd growth from zinc rods. Place Cd in high speed blender, add 500 ml H_2O and blend solids 2 sec. Wash fine metal particles through a sieve with water, collecting only the 20–40 mesh particles.

Fill reduction column (50-ml buret) with H_2O and add a 2 cm plug of glass wool. Press entrapped air from the glass wool while pushing it to

[1]Method obtained through courtesy of Dr. Fred Albright, Lancaster Laboratories, Lancaster, Pennsylvania.

the bottom of the column using a glass rod. Add Cd to a depth of 10 cm using very gentle tapping. Wash column with 25 ml of 0.1 *N* HCl, two 25-ml portions H_2O, and finally 25 ml of ammonia chloride buffer diluted (1+9). Keep column covered with sodium chloride solution when not in use.

Columns can be used repeatedly if kept under salt solution between analyses. When a succession of highly proteinaceous or other soluble organic containing samples are treated, flow rate may decrease gradually. Repeated 25 ml 0.10 *N* HCl treatments may restore original flow rate; if not, prepare new column. A reproducible flow-rate is important. Actual rate can be 3–5 ml/min but, once established it should be identical for samples and standards.

Reagents

Ammonium chloride buffer solution, pH 9.6. Dissolve 50 g NH_4Cl in 500 ml distilled water and adjust pH with NH_4OH. Dilute to 1 liter with water. Stable indefinitely.

Aluminum hydroxide. Dissolve 125 g $AlK(SO_4)_2 \cdot 12H_2O$ in 1 liter distilled water. Warm to 60°C and slowly add 55 ml concentrated NH_4OH with stirring. Let the mixture stand for about 1 hr. Wash the suspension by vacuum filtration, followed by re-suspension in clean distilled water. Repeat the washing technique until the filtrate is free from ammonia, chlorides, nitrate, and nitrite. After the final settling, decant the clear liquid to obtain a concentrated suspension. Shake the residue vigorously before use to resuspend the precipitate before use.

Sodium chloride solution. Dissolve 100 g NaCl in 500 ml H_2O. Add 50 ml ammonium chloride buffer solution and dilute to 1 liter with H_2O. Stable indefinitely.

Sulfanilamide solution 0.5%. Dissolve 1.25 g sulfanilamide in 250 ml HCl (1+1). Stable 1 to 2 months.

Coupling reagent. Dissolve 0.5 g *N*(1-naphthyl) ethylenediamine · 2HCl in 100 ml H_2O. Store in brown bottle in refrigerator. Solution is stable several weeks.

Nitrate nitrogen working solution (3 μg NO_3-N/ml). Dissolve 0.867 g KNO_3 in 1 liter H_2O. Dilute 25 ml to 1000 ml with distilled water. Prepare fresh for each analysis.

Procedure

Place 2.000 g sample of finely ground mixed meat mass into 250-ml Erlenmeyer flask. Add 5 ml NH_4Cl buffer solution, 25 ml aluminum hydroxide slurry and 20 ml double distilled water. Place on mechanical shaker for 20 min, filter through Whatman No. 41 filter paper into a 100-ml volumetric flask, washing paper until flask contains 100 ml using double distilled water.

Pipette a 20-ml aliquot onto cadmium column that has just been washed with 10 ml of double distilled water. (Never allow column to go dry.) For high protein meat products make a 10× dilution and place 20 ml of the diluted solution on the column. Wash column with 15 ml NaCl solution followed by 10 ml double distilled water and collect total eluant in 100-ml volumetric flask. Rinse column with 10 ml double distilled water between samples.

Add 5 ml sulfanilamide to flask, mix well, let stand for 3 min. Add 2 ml coupling reagent, mix and dilute to 100 ml with double distilled water. Allow color to develop at least 20 min, read absorbance at 540 nm against a reagent blank that has been carried through the entire procedure and color developed with sulfanilamide and coupling reagent. The developed color is stable at least 2 hr.

Calculations

Preparation of standard curve. Place 0, 1, 2, 3, 4, and 5 ml of nitrate standard solution into separate 100 ml beakers. Add 5 ml of buffer solution to each standard and dilute to about 20 ml. Pass standards through column and wash as with samples. Collect eluant in 100 ml volumetric flasks and develop color as with samples. Read absorbance.

$$\text{ppm } NO_3 = (\text{graph reading})(\text{dilution factor})(11.08) - (\text{ppm } NO_2)(1.348)$$

Precautions

A new standard curve is run when new column or color development solution is prepared.

Keep reagents fresh as described above.

Establish limits of the spectrophotometer used.

NITRITE

Theory

Determination of nitrite in cured meat depends on formation of a red azo-color by interaction of nitrites with Griess reagent (sulfanilic acid plus α-naphthylamine).

The salts of nitrite are first extracted from meat samples with hot water and the soluble proteins of the meat coagulated by a mercuric chloride solution.

After cooling, the solution is made up to 500 ml volume and a small aliquot of 1 to 10 ml is then taken for the color development with Griess reagent, the intensity of which is measured spectrophotometrically.

Apparatus

2 500-ml Erlenmeyer flasks
Spectrophotometer

2 50-ml volumetric flasks
Pipette
Blender
Oven

Reagents

Hot alkaline water. Take approximately 300 ml distilled water in a 400-ml beaker. Make it just alkaline to litmus paper using 0.1 *N* sodium hydroxide. Heat close to boiling before using.
Sulfanilic acid solution. Dissolve 0.3334 g of the reagent in 15 ml glacial acetic acid. Make up to 100-ml volume with water. Very stable.
Naphthylamine. Dissolve 0.1 g of the reagent in 15 ml glacial acetic acid and make up to 100 ml volume with water. Stable for 2 to 3 weeks. Keep in a brown bottle.
Glacial acetic acid
Saturated mercuric chloride solution

Procedure

Weigh 20.0 g of a meat sample and place it in a blender. Mix thoroughly, using a small amount of hot alkaline water. Transfer the contents to a 500-ml Erlenmeyer flask. Wash the container and cover with several portions of the hot water, adding all washings to the flask.

Add enough hot alkaline water to bring the volume to approximately 300 ml. Place the flask with a stopper in an oven at 80°C for 2 hr, shaking occasionally.

Add 5 ml of a saturated mercuric chloride solution; mix and cool to room temperature.

Transfer the entire contents to a 500-ml volumetric flask; bring to volume with water and shake well.

Filter a portion through No. 42 Whatman filter paper into a test tube. Pipette 2 ml aliquot of the filtered solution into a 50-ml volumetric flask in which 1 ml of sulfanilic acid and 1 ml of α-naphthylamine reagents are already present. Fill the flask to the 50-ml volume mark with water, mix well, and let it stand for 1 hr to develop the red color. Prepare a blank containing the reagents only and water.

Transfer a portion of solution to a photometer cell and determine the absorbance at 520 nm, setting instrument to zero absorbance with the blank.

Take the reading and find the percent nitrogen directly from a prepared chart or calibration curve.

The chart should be calibrated on the basis of a 20-g sample, 2 ml aliquot (out of 500-ml volume) and 50-ml volumetric flask where the color is developed.

Any deviations from the above constant weights and volumes would involve necessary corrections.

$$\% \text{ nitrite} = \% \text{ nitrogen} \times 3.284$$
$$\% \text{ sodium nitrite} = \% \text{ nitrogen} \times 4.921.$$

MEAT PIGMENTS IN CURED MEAT PRODUCTS

Theory

This procedure is based on the extraction of hematin from cured meat products in a water/acetone solvent. The moisture content of the meat sample is normally taken into account such that a calculated 80% acetone/water extraction results. Procedure and calculations have been worked out by H. C. Hornsey in which nitrosohemoglobin versus total acid hematin are quantitatively determined as parts per million for a given meat sample size and a given acetone/water ratio. The degree of meat curing is expressed directly as percentage.

Good or acceptable pigment conversion generally falls in an area between 80 and 90% of the pigment as nitrosohemochromagen.

Levels of about 100 ppm are considered a fair minimum for total pigments available for conversion. Generally, levels above 140 ppm for all meat products and higher for all beef products are very good. Pigment levels depend a great deal on the type of materials used in the sausage products.

Apparatus

2 45 ml polypropylene centrifuge tubes with covers
1 glass stirring rod with tapered end to fit tip of the centrifuge tube
2 Pyrex test tubes, 15 × 90 mm
Spectrophotometer with 1-cm cells
2 glass funnels, 50-mm diameter
2 watch glasses, 2-in. diameter

Reagents

Acetone (Sol. 1) 18.0 ml distilled water in a 200 ml volumetric flask; add C. P. acetone, mix and bring to volume.

Acetone (Sol. 2). To 4.0 ml concentrated hydrochloric acid, add distilled water, mix and bring to 20-ml volume. Transfer the diluted hydrochloric acid to a 200-ml volumetric flask, add C. P. acetone, mix and bring to volume with additional C. P. acetone.

Procedure

Procure meat sample by means of a No. 6 cork borer. Weigh out exactly 2.0 g sample and transfer to the polypropylene centrifuge tube.

Add 9.0 ml acetone (Sol. 1) to the centrifuge tube by means of a pipette. Macerate the meat mass thoroughly with the glass stirring rod (2 to 3 min required). Stopper the tube with centrifuge tube cover and mix by gentle swirling. Allow to stand 10 min, then filter through 2 No. 42 Whatman papers (9.0 cm diam.) into a test tube. The above operations should be carried out in very subdued light to lessen fading of pigment during extraction.

Transfer filtrate into a 1-cm Beckman cell and read optical density within 1 hr at 540 nm and calculate as nitroso pigment.

Prepare another 2.0 g sample as above and transfer to another polypropylene centrifuge tube. Add 9.0 ml acetone (Sol. 2) by means of a pipette. Macerate the meat sample thoroughly with the stirring rod and allow to stand 1 hr before filtering. Filter the extract into another test tube and read the optical density at 640 nm. Calculate as total pigment.

Calculation of Results

$$\text{ppm nitroso pigment} = \text{optical density (at 540 nm)} \times 290$$
$$\text{ppm total pigment} = \text{optical density (at 640 nm)} \times 680$$

$$\%\ \text{conversion} = \frac{\text{ppm nitroso pigment}}{\text{ppm total pigment}} \times 100$$

Test Limitation

The procedure has been scaled down to a small sample size; therefore, the meat sample should be as homogeneous as possible. The sampling is taken by means of a cork borer using the center portion of a meat product, such as a frankfurter, to eliminate other coloring substances as food dye ordinarily found at the peripheral surface. Filtrate must be crystal clear, which is easily accomplished where two combined fine filter papers are used. Percent conversion is calculated on a theoretically possible 100% if all hematin can actually be converted to nitroso pigment.

PHOSPHATE

In this procedure a partially dried sample is ashed and the phosphates are hydrolyzed to the ortho form and separated as quinolinium phosphomolybdate.

Theory

Phosphomolybdic acid is formed first (in the presence of citrate), which then forms quinolinium phosphomolybdate (QPM), with the base, quinoline. The citrate in the reagent complexes any ammonium ion, thereby preventing the precipitation of ammonium phosphomolybdate.

The original version of this procedure required two separate solutions to form the QPM precipitate: a citric–molybdic acid solution and quinoline solution. The inclusion of acetone permitted these two solutions to be combined, such that a single reagent could be employed as the precipitant. This reagent is known as the quimociac reagent, and derives its name from the *QUI* noline, *MO*lybdate, *CI*trate and *AC*etone constituents of the mixture.

Apparatus

Gooch crucible (Coors No. 4)
Glass fiber filter paper (2.4-cm circles)

Place the Gooch crucible containing a glass fiber filter disk in the suction apparatus. Center paper and wash with approximately 50 ml water. Dry the crucible at 250°C for 30 min in a forced-draft oven, cool in desiccator and weigh.

Chemicals

Dilute nitric acid. 1 volume concentrated nitric acid plus 4 volumes water

Quimociac reagent. Dissolve 70 g sodium molybdate dihydrate ($Na_2MoO_4 \cdot 2H_2O$) in 150 ml water. Dissolve 60 g citric acid in a mixture of 85 ml nitric acid and 150 ml water and cool. Gradually add the molybdate solution to the citric–nitric acid solution while stirring. Dissolve 5 ml synthetic quinoline, with stirring, in a mixture of 35 ml concentrated nitric acid and 100 ml water. Gradually add this solution to the molybdic–nitric acid solution, mix well, and let stand for 24 hr. Filter, and 280 ml acetone, dilute to 1 liter with water, and mix. Store in either a noncolored polyethylene bottle or a dark brown glass bottle.

Procedure

Weigh accurately about 2.5 g (no more than 25 mg P_2O_5) of sample into an ashing dish and dry for 30 min at 125°C in a forced-draft oven. Ash at 550°C until white or nearly white ash is obtained.

Cool; add 25 ml dilute nitric acid and heat on a steam bath for 30 min. Filter into a 400-ml beaker. Wash dish and paper with distilled water such that total volume in beaker is approximately 100 ml.

At this point, run a reagent blank in parallel, using 25 ml dilute nitric acid and 75 ml distilled water. Add 50 ml quimociac reagent to test beaker, cover with a watch glass, and boil for 1 min. (Do not use an open flame.) Cool to room temperature while swirling carefully; transfer the precipitate to the prepared crucible and wash 5 times with 25 ml portions of distilled water, allowing each portion to drain thoroughly (use suction) before adding the next portion. Dry the crucible and contents for 30 min at 250°C, cool in a desiccator and weigh.

Calculations

$$\text{phosphorus content} = \frac{(100)(A-B)(0.014)}{C} - (0.0106)(\%\ \text{meat protein})$$

where A = weight of precipitate, B = weight of blank, C = sample weight. 0.014 = gravimetric factor derived from atomic weight of phosphorus = 30.97 divided by molecular weight of (QPM) = 2212.71. 0.0106 = factor to correct for the phosphorus content of meat protein

The following table lists phosphates and their corresponding factors:

Name and Formula		*Factor*
Disodium phosphate	Na_2HPO_4	4.58
Sodium hexametaphosphate	$(NaPO_3)_6$	3.29
Sodium tripolyphosphate	$Na_5P_3O_{10}$	3.96
Tetrasodium pyrophosphate	$Na_4P_2O_7$	4.29
Sodium dihydrogen phosphate	NaH_2PO_4	3.87
Sodium acid pyrophosphate	$Na_2H_2P_2O_7$	3.58

SALT

In this procedure, the sodium chloride content is determined by the well-known Volhard method, first described in 1874. The sample is treated with silver nitrate and nitric acid and then wet-ashed, followed by back-titration of the excess silver nitrate with potassium thiocyanate.

Theory

From the outset, the order in which silver nitrate and nitric acid are added to the flask is quite critical. The silver nitrate solution must be added first, followed by the concentrated nitric acid. This order of addition ensures complete precipitation of the chlorides. If nitric acid is added first, loss of chloride by volatilization as hydrochloric acid could occur, since hydrochloric acid has a far greater vapor pressure than nitric acid.

The volume of silver nitrate solution added must be in excess of that required to react with the chloride content of the sample. The concentrated solution of potassium permanganate is added to oxidize any organic matter not disposed of by the nitric acid. Should too much potassium permanganate be accidentally added, color removal can be effected by the addition of small quantities of sugar.

Following boiling, cooling, and dilution, add nitrobenzene or diethyl ether and back-titrate the excess silver nitrate with potassium thiocyanate solution, employing ferric ammonium sulfate solution as an indicator.

After all the silver has been back-titrated, an excess of thiocyanate may react with the precipitated silver chloride, since the solubility product of silver thiocyanate is 1/100 that of silver chloride.

$$S_{\mathrm{AgCNS}} = 1.0 \times 10^{-12}$$
$$S_{\mathrm{AgCl}} = 1.1 \times 10^{-10}$$

The addition of nitrobenzene or diethyl ether overcomes this difficulty by coating the precipitated silver chloride, thereby withdrawing it from the action of the thiocyanate solution.

The $FeNH_4(SO_4)_2$ reacts with an excess of thiocyanate, forming the red-colored complex, ferric thiocyanate, $(FeCNS)^{2+}$, indicating the end point has been reached.

Reagents

Ferric alum indicator. Saturated aqueous solution of reagent grade $FeNH_4(SO_4)_2 \cdot 12H_2O$.

Silver nitrate, 0.100 *N*. Dissolve 17.04 g silver nitrate, previously dried at 110°C, in distilled water, and dilute to 1 liter. Standardize, using excess silver nitrate against 0.100 *N* sodium chloride (5.845 g/liter), according to the Volhard method.

Potassium thiocyanate, 0.100 *N*. Dissolve 9.72 g reagent-grade potassium thiocyanate in distilled water, and dilute to 1 liter. Verify the strength of this solution as follows. Pipette 25 ml standard silver nitrate solution into a 300 ml Erlenmeyer flask; add 80 ml distilled water 5 ml of 1 + 1 nitric acid, and 2 ml of the ferric alum indicator. Titrate with potassium thiocyanate solution to a permanent light brown end point. The ratio of the volume of potassium thiocyanate to the volume of silver nitrate should be 1 : 1.

Potassium permanganate, 5% aqueous solution.

Procedure

Weigh 3 ± 0.05 g of finely comminuted and thoroughly mixed sample into a 300-ml Erlenmeyer flask. Add 25.0 ml of 0.100 *N* silver nitrate solution; swirl flask until the sample and solution are in intimate contact then add 15 ml concentrated nitric acid. Boil until meat dissolves and add potassium permanganate until color disappears and solution becomes almost colorless. Add 25 ml water; boil for 5 min; cool and dilute to 150 ml with water.

Add 1 ml nitrobenzene or 25 ml diethyl ether, 2 ml of the ferric alum indicator and shake vigorously to coagulate the precipitated silver chloride. Titrate the excess silver nitrate with potassium thiocyanate solution to a permanent light-brown end point.

Calculations

$$\% \text{ salt} = \frac{(25.0 \text{ ml} - \text{ml KCNS})\ (0.1\ N)\ (5.85)}{\text{sample weight}}$$

$$\% \text{ sodium} = \frac{\text{atomic weight of Na } (22.997) \times 1.00}{\text{atomic weight of NaCl } (58.45)}$$

% Na = 39.34% or the amount of Na is equal to 39.34 mg per 100 mg of salt.

CEREAL

Cereal is added to meat food products as a binder. In this procedure, the cereal starch is dissolved in 1 + 1 hydrochloric acid, re-precipitated, and determined gravimetrically. A rapid, semiquantitative method is also described.

Theory

As in the soybean flour and soy protein concentrate determinations, the meat is rendered soluble by treatment with an alcoholic solution of caustic potash; spices and cereal starch remain as a sediment. If a semiquantitative estimation of the cereal content is desired, this residue volume is read and a deduction allowed for spices.

A more accurate quantitation is obtained if the cereal starch is dissolved in 1 + 1 hydrochloric acid, re-precipitated with 95% ethanol, dried and weighed.

Apparatus

Centrifuge
Centrifuge tubes, Goetz, 100-ml
Gooch crucible

Chemicals

95% ethanol
Alcoholic caustic potash solution, 8%. Dissolve 50 g potassium hydroxide in 300 ml 95% ethanol, and dilute to 500 ml with 95% ethanol.
Dilute hydrochloric acid, 1 + 1. Mix 1 volume concentrated hydrochloric acid with 1 volume distilled water.

Semiquantitative Procedure

This procedure is applicable only in the absence of soybean flour and soy protein concentrate.

Weigh 10.0 g of sample into a 100-ml Goetz tube. If corn syrup, corn syrup solids, nonfat dry milk, and/or calcium-reduced dried skimmilk are present, extract with two successive 50-ml portions of warm distilled water, shake, centrifuge, decant, and discard the supernatant liquid after each extraction.

Add 50 ml 8% alcoholic potassium hydroxide solution and digest in a steam bath for 20 min with occasional stirring. Dilute to 100 ml with 95% ethanol. Allow to stand for 1 hr and read volume of sediment in tube.

$$\% \text{ cereal} = \text{volume of sediment in tube} - 0.5\% \text{ for spices, if present.}$$

Gravimetric Procedure

Centrifuge the 100 ml suspension for 5 min. Decant and discard the supernatant liquid. Wash the residue with 25 ml 95% ethanol, stirring the sediment thoroughly. Centrifuge, decant, and discard the supernatant liquid.

Add 50 ml of 1 + 1 hydrochloric acid, mix thoroughly, stopper and shake for 1 min. Centrifuge at 2000 rpm for 4 min. If supernatant liquid is not clear, filter it through a double-thickness No. 541 Whatman paper, or equivalent.

Transfer 25 ml of clear supernatant liquid to a 150 ml beaker containing 75 ml 95% ethanol; mix well, and let stand for 1 hr. Filter through a tared Gooch crucible, wash with two 25-ml portions of 95% ethanol, dry for 30 min at 75°C, and weigh.

Calculations

$$\% \text{ cereal} = \frac{(A - B)\,(1.45)\,(100)}{C/2}$$

where A = weight of Gooch crucible plus starch, B = weight of Gooch crucible, C = sample weight, 1.45 = factor for converting from starch to cereal, assuming that cereals contain an average starch content of 69%.

SOYBEAN FLOUR AND SOY PROTEIN CONCENTRATE

Dilute acid dissolves the hemicelluloses of soybean flour and soy protein concentrate, but does not affect cereal flour starch. In this method soybean flour or soy protein concentrate is determined in the presence of cereal flour.

Theory

If a meat food product is heated in an alcoholic solution of caustic potash, the fat is saponified and the protein hydrolyzed. This treatment renders the major solid components of meat (fat and protein) soluble in the medium. Spices, cellulose, and starch (from cereal, if present) remain as a sediment.

Dilute acid is then employed to dissolve the soybean flour hemicelluloses, which are subsequently re-precipitated with 95% ethanol and quantitated following a carefully controlled centrifugation. Quantitation is done by employing the empirical factors, 6.0 for soybean flour and 2.5 for soy protein concentrate.

Because of the empirical nature of this determination, it is imperative that the time and speed of centrifugation be closely adhered to.

Apparatus

Centrifuge
Centrifuge tubes, Goetz, 100-ml

Reagents

95% ethanol

Alcoholic caustic potash solution (8%). Dissolve 40 g potassium hydroxide in 300 ml 95% ethanol, and dilute to 500 ml with 95% ethanol.

Dilute hydrochloric acid (1 + 3). Mix 1 volume concentrated hydrochloric acid with 3 volumes distilled water.

Procedure

Weigh 10.0 g of sample into a 100-ml Goetz tube. Add 50 ml 8% alcoholic potassium hydroxide solution and digest in a steam bath for 30 min with occasional stirring. Shake well and centrifuge for 4 min. Decant and discard the supernatant solution. Wash residue with 25 ml 95% ethanol, stirring sediment thoroughly. Centrifuge and decant. Discard the alcoholic solution.

Add 50 ml dilute hydrochloric acid, mix thoroughly, stopper, and shake for 1 min. Centrifuge at 2000 rpm for 4 min. (Retain residue for cereal determination.)

If supernatant is not clear, filter it through a double thickness No. 541 Whatman paper or equivalent. Transfer 25 ml of clear supernatant to a second Goetz tube containing 75 ml 95% ethanol, shake well, and allow to stand for 1 hr.

Accelerate from 0 to 1500 rpm over 1 min, and centrifuge at 1500 rpm for exactly 2 min. Read volume of sediment in tube.

Calculations

$$\% \text{ soybean flour} = \text{volume of sediment} \times 6$$
$$\% \text{ soy protein concentrate} = \text{volume of sediment} \times 2.5$$

Note: The sediment remaining from the dilute hydrochloric acid leaching may be used to determine cereal content, if present. Decant the hydrochloric acid. Mix the residue with 50 ml of 1:1 hydrochloric acid, and proceed as under gravimetric section of Cereal Determination.

LACTOSE

Lactose, which is also called milk sugar, comprises the principal carbohydrate in milk and is a reducing disaccharide. Since nonfat dry milk and calcium-reduced dry skimmilk are commonly utilized as protein extenders in meat products, their lactose content is used to measure the amount of these milk products added to processed meats.

Theory

Determination of lactose is based on the fact that it is not fermentable by ordinary bakers' yeast. Maltose, which is the product of starch hydrolysis, is also not fermented by bakers' yeast. Thus, if corn syrup or corn syrup solids are added to meat products, a maltose-acclimated yeast must be prepared in order to ferment the maltose occurring in both of these additives. Active dry yeast can also be used instead of bakers' yeast, but special care must be taken to avoid destruction of the organisms.

Lactose is determined after first removing other reducing sugars by yeast fermentation. The amount of lactose is then determined by measuring the reducing power of the meat product. In practice, a protein-free filtrate of the meat sample is treated with Benedict's solution, with the resulting reduced copper complex being determined by adding an excess of iodine solution and back titrating the excess iodine ion with sodium thiosulfate, using starch solution as the indicator.

Reagents

Washed yeast suspension. Mix four cakes of bakers' yeast (or 30 g active dry yeast) to a smooth suspension with 300 ml distilled water. If active dry yeast is used, the yeast must be added to the water. Centrifuge for 5 min and discard the aqueous layer. Repeat 4 more times, or until the supernatant is clear following centrifugation. Finally re-suspend the yeast in distilled water, dilute to 200 ml with distilled water, and refrigerate at about 4°C.

Acclimated yeast suspension: Prepare acclimating medium by dissolving each of the following ingredients in a small amount of distilled water and adding, in the order given, to 1 liter distilled water, 2.0 g anhdyrous magnesium sulfate, 4.0 g ammonium chloride, 2.0 g anhydrous dipotassium hydrogen phosphate, 1.0 g potassium chloride, 0.04 g $FeSO_4 \cdot 7H_2O$, 1.4 g peptone, and 40.0 g technical maltose. Dilute to 2 liters, warm, and filter. Bring filtrate to a rolling boil and allow it to cool to room temperature. Shake well the washed yeast suspension, remove 100 ml, and centrifuge. Discard the aqueous layer, add the washed yeast to 1 liter of the acclimating medium and incubate for approximately 24 hr at 30°C, stirring frequently the first few hours. Separate yeast by decanting and centrifuging. Wash twice with distilled water and repeat incubation with the remaining 1 liter of acclimating medium. Separate yeast again, wash 4 to 5 times with distilled water. Suspend the yeast in distilled water, dilute to 100 ml with distilled water and refrigerate at about 4°C.

Dilute hydrochloric acid: 1 volume conc. hydrochloric acid plus 4 volumes distilled water.

Phosphotungstic acid, 20% wv

Chlorophenol red indicator. Dissolve 0.1 g chlorophenol red in 2.4 ml 0.1 *N* sodium hydroxide and dilute to 250 ml with distilled water.

Bromthymol blue indicator. Dissolve 0.1 g bromthymol blue in 1.6 ml 0.1 *N* sodium hydroxide and dilute to 250 ml with distilled water.

Buffer solution pH 4.8. Prepare 0.1 *M* citric acid (19.21 g/liter) and 0.2 *M* disodium hydrogen phosphate (28.4 g anhydrous/liter). Mix solutions in proportions of 10.14 ml citric acid to 9.86 ml disodium hydrogen phosphate and adjust to pH 4.8. Store in refrigerator and discard if solution becomes turbid.

Benedict solution. Dissolve 16 g $CuSO_4 \cdot 5H_2O$ in 150 ml distilled water. Dissolve 150 g sodium citrate, 130 g anhydrous sodium carbonate, and 10 g sodium bicarbonate in 650 ml distilled water. Combine the two solutions. Cool and dilute to 1 liter with distilled water and then filter.

Dilute acetic acid. Dilute 240 ml glacial acetic acid to 1 liter with distilled water.

Dilute phosphoric acid. Dilute 240 ml phosphoric acid to 1 liter with distilled water.

Iodine standard solution. Dissolve 10.2 g potassium iodide in a minimum quantity of distilled water and use this solution as a solvent for 5.08 g iodine. Filter, if necessary, through glass fiber filter paper and dilute to 1 liter with distilled water.

Sodium thiosulfate standard solution. Dissolve 9.92 g $Na_2S_2O_3 \cdot 5H_2O$ in recently boiled, cooled distilled water. Add 0.1 g sodium carbonate and dilute to 1 liter with distilled water.

Starch indicator solution. Triturate 2 g soluble starch and 10 mg mercuric iodine with a small amount of distilled water. Add the suspension slowly to 500 ml boiling distilled water, and boil until clear.

Lactose standard solution. Dissolve 1.5789 g lactose monohydrate in distilled water and dilute to 1 liter with distilled water (10 ml = 15 mg anhydrous lactose).

Procedure

Weigh a 20.0 g sample into a 200-ml volumetric sugar flask. Add 50 ml distilled water, stir or shake to break up any lumps and heat in a steam bath for 30 min. Cool to room temperature. Add 20 ml dilute hydrochloric acid and dilute to volume using bottom of the fat layer as a meniscus. Add 10 ml 20% phosphotungstic acid solution. Mix and let stand for a few minutes and then filter through moistened filter paper. Pipette 40 ml filtrate into a 50-ml volumetric flask. If corn syrup or corn syrup solids are absent, neutralize just to the acid side of bromthymol blue indicator. Dilute to volume with distilled water and mix. If corn syrup or corn syrup solids are present, neutralize just to the acid side of chlorophenol red indicator. Add 5 ml of the buffer solution and dilute to volume with distilled water, and then mix.

Transfer about 40 ml of this solution to a centrifuge tube to which 5 ml of acclimated yeast suspension (washed yeast if corn syrup or corn syrup solids are absent) has been added, and from which the water has been separated. Mix yeast and sample well, and incubate washed yeast for 1 hr at 30°C, or acclimated yeast for 3 hr at 30°C. Stir frequently. Centrifuge and determine reducing sugars. Pipette 10 ml of clear supernatant into a 300-ml Erlenmeyer flask. Add 20 ml Benedict solution. Bring to boil in 3 to 5 min and boil for exactly 3 min. Remove from heat, cool rapidly, add 100 ml distilled water and 10 ml dilute acetic acid slowly while swirling. Add a definite volume of standard iodine solution (15 ml for about 1.5% lactose, or 30% excess), and agitate to dissolve the cupric oxide. Allow flask to stand at least 5 min. Add 20 ml of the dilute phosphoric acid solution and titrate excess iodine with standard sodium thiosulfate solution using the starch solution as indicator.

Determine iodine/sodium thiosulfate ratio by using 10 ml distilled water, and carrying through determination as above, beginning with addition of Benedict solution.

$$\text{Ratio A} = \frac{\text{volume iodine (ml)}}{\text{1.0 ml sodium thiosulfate}}$$

Determine lactose/iodine ratio by using 10 ml of standard lactose solution, and carrying through determination as above, beginning with addition of Benedict solution

$$\text{Ratio B} = \frac{\text{mg lactose}}{\text{1.0 ml iodine}}$$

Calculations

$$\%\ \text{lactose} = \frac{100\ [\text{ml iodine added to flask} - (A)\ (\text{ml sodium thiosulfate required for back titration})]\ [B]}{C}$$

where A and B = ratios defined above and C = milligrams of sample in aliquot (consider the volume of the original sample solution as 200 ml, rather than 210 ml, to take into account the volume occupied by the sample).

% nonfat dry milk or % calcium-reduced dry skimmilk =
(% lactose × 2) − correction

Correction: 0.4% in the absence of corn syrup or corn syrup solids, and 0.8% in the presence of corn syrup or corn syrup solids.

Precautions

This procedure is based on the analysis of a labile component of nonfat dry milk or calcium-reduced dry skimmilk—a fact that should be kept constantly in mind. Lactose can be readily fermented to lactic acid by certain microorganisms, especially *Streptococcus lactis,* which is generally present in muscle tissue. Lactose can also be quickly hydrolyzed to glucose and galactose by the action of hot, dilute acids. If these reactions occur, the analytical results will be low, since nonfat dry milk or calcium-reduced dry skimmilk is calculated on the basis of amount of lactose found. This analysis should be initiated as soon as the sample is ground, and, if possible, completed on the same day. The small amount of water initially added to the 20-g sample should be at room temperature when added to the sugar flask. If it is hot, coagulation of the meat and milk protein may occur, making it difficult to macerate the sample and leach out the lactose. If, following the 30-min heating time on the steam bath, the flask and contents are not cooled to room temperature before adding the hydrochloric acid, loss of lactose may take place by hydrolysis.

The viability and potency of the acclimated yeast suspension can be determined as follows: Weigh 500 mg maltose and 800 mg dextrose and transfer to a 100-ml volumetric flask. Dilute to volume with distilled water. Stopper and mix well. Pipette a 10-ml aliquot into a 50-ml volumetric flask and proceed through the incubation procedure. Boil 10 ml of this solution (following centrifugation), with 20 ml of Benedict's solution for exactly 3 min. This should yield no precipitate or suspension of cuprous oxide, indicating that the yeast did, in fact, ferment the sugars as desired. If a precipitate or suspension is obtained, the yeast should be discarded. This is the only procedure which will definitely assure that the yeast is "working" properly. NOTE: If washed yeast is used, weigh only 800 mg dextrose. Do not use any maltose.

The reduction portion of this method is extremely critical because it involves an empirical procedure. The 3-min boiling time must be strictly adhered to, and the flask should be cooled rapidly after boiling. This may be accomplished by inverting a beaker over the neck of the flask and allowing a stream of cold tap water to flow over the flask.

Titration should be performed immediately after addition of the phosphoric acid to avoid any possible loss of iodine. Use of iodine flasks, although they are considerably more expensive than Erlenmeyer flasks, will also serve to avoid loss of iodine.

CORN SYRUP SOLIDS

Corn syrup solids is added to meat food products as a flavoring agent. In this procedure, the amount of corn syrup solids added is determined by analyzing the product for its maltose content.

Theory

Because recent studies have indicated that the maltose content of corn syrup solids is quite variable, it is imperative that different lots of corn syrup solids be analyzed for this constituent.

If corn syrup is used, a sample should be analyzed for moisture content, and only those samples which assay 20% or less should be permitted to be added to the product.

Products to which corn syrup solids or corn syrup and nonfat dry skimmilk or calcium-reduced dried skimmilk have been added are analyzed for corn syrup solids content by determining the difference between the reducing sugars remaining in the samples after the samples have been subjected to two fermentations by (1) washed yeast (which leaves lactose and maltose), and (2) yeast acclimated to maltose (which leaves lactose).

Products to which corn syrup solids or corn syrup, but neither nonfat dry milk nor calcium-reduced dried skimmilk, have been added are analyzed for corn syrup solids content by determining the amount of maltose present following a washed yeast fermentation.

Reagents

Washed yeast suspension. Mix 4 cakes of bakers' yeast (or 30 g active dry yeast) to a smooth suspension with 300 ml distilled water; if active dry yeast is used, the yeast must be added to the water. Centrifuge for 5 min and discard the aqueous layer. Repeat 4 more times, or until the supernatant is clear, following centrifugation. Finally re-suspend the yeast in distilled water, dilute to 200 ml with distilled water, and refrigerate at about 4°C.

Acclimated yeast suspension. Prepare acclimating medium by dissolving each of the following ingredients in a small amount of distilled water and adding in the order given to 1 liter distilled water: 2.0 g anhydrous magnesium sulfate, 4.0 g ammonium chloride, 2.0 g anhydrous dipotassium hydrogen phosphate, 1.0 g potassium chloride, 0.04 g $FeSO_4 \cdot 7H_2O$, 1.4 g peptone, and 40.0 g technical maltose. Dilute to 2 liters, warm, and filter. Bring filtrate to a rolling boil and allow it to cool to room temperature. Shake the washed yeast suspension well, remove 100 ml, and centrifuge. Discard the aqueous layer; add the washed yeast to 1 liter of the acclimating medium and incubate for approximately 24 hr at 30°C, stirring frequently the first few hours. Separate yeast by decanting and centrifuging. Wash twice with distilled water, and repeat incubation with the remaining 1 liter of of acclimating medium. Separate yeast again, wash 4 to 5 times with distilled water. Suspend the yeast in distilled water, dilute to 100 ml with distilled water and refrigerate at about 4°C.

Dilute hydrochloric acid. 1 volume conc. hydrochloric acid plus 4 volumes distilled water.

Phosphotungstic acid, 20% w/v.

Chlorophenol red indicator. Dissolve 0.1 g chlorophenol red in 2.4 ml 0.1 *N* sodium hydroxide and dilute to 250 ml with distilled water.

Bromthymol blue indicator. Dissolve 0.1 g bromthymol blue in 1.6 ml 0.1 *N* sodium hydroxide and dilute to 250 ml with distilled water.

Buffer solution, pH 4.8. Prepare 0.1 *M* citric acid (19.21 g/liter) and 0.2*M*disodium hydrogen phosphate (28.4 g anhydrous/liter) solutions. Mix solutions in proportions of 10.14 ml citric acid to 9.86 ml disodium hydrogen phosphate and adjust to pH 4.8. Store under refrigeration and discard if solution becomes turbid.

Benedict solution. Dissolve 16 g $CuSO_4 \cdot 5H_2O$ in 150 ml distilled water. Dissolve 150 g sodium citrate, 130 g anhydrous sodium carbonate, and 10 g sodium bicarbonate in 650 ml distilled water. Combine the two solutions. Then cool and dilute to 1 liter with distilled water and filter.

Dilute acetic acid. Dilute 240 ml glacial acetic acid to 1 liter with distilled water.

Dilute phosphoric acid. Dilute 240 ml phosphoric acid to 1 liter with distilled water.

Iodine standard solution. Dissolve 10.2 g potassium iodide in a minimum quantity of distilled water and use this solution as a solvent for 5.08 g iodine. Filter, if necessary, through glass fiber filter paper and dilute to 1 liter with distilled water.

Sodium thiosulfate standard solution. Dissolve 9.92 g $Na_2S_2O_3 \cdot 5H_2O$ in recently boiled, cooled, distilled water. Add 0.1 g sodium carbonate and dilute to 1 liter with distilled water.

Starch indicator solution. Triturate 2 g soluble starch and 10 mg mercuric iodide with a small amount of distilled water. Add the suspension slowly to 500 ml boiling distilled water, and boil until clear.

Maltose standard solution. Dissolve 1.5789 g maltose monohydrate in distilled water and dilute to 1 liter with distilled water (10 ml = 15 mg anhydrous maltose).

Procedure

For samples containing both corn syrup solids or corn syrup and nonfat dry milk or calcium-reduced dried skimmilk, use procedure given for lactose, pipetting two 40-ml aliquots of protein-free filtrate into 50-ml volumetric flasks. Neutralize one just to the acid side of bromthymol blue indicator, dilute to volume with distilled water, and mix. Neutralize the other just to the acid side of chlorophenol red indicator, add 5 ml buffer solution, dilute to volume with distilled water, and mix. To a centrifuge tube add 5 ml washed yeast suspension; to another centrifuge tube add 5 ml acclimated yeast suspension. Separate the water by centrifuging and decanting. Transfer about 40 ml of the unbuffered solution to the centrifuge tube containing the washed yeast. Transfer about 40 ml of the buffered solution to the centrifuge tube containing the acclimated yeast. Mix yeast and sample well. Incubate washed yeast for 1 hr at 30°C and acclimated yeast for 3 hr at 30°C, stirring frequently. Continue procedure as given for lactose, except that, in lieu of a lactose:iodine ratio, determine a maltose:iodine ratio using 10 ml of standard maltose solution.

$$\text{Ratio B} = \frac{\text{mg maltose}}{\text{1.0 ml iodine}}$$

For samples containing either corn syrup solids or corn syrup, but neither nonfat dry milk nor calcium-reduced dried skimmilk, pipette a single 40-ml aliquot of protein-free filtrate into a 50-ml volumetric flask. Neutralize just to the acid side of bromthymol blue indicator, then dilute to volume with distilled water and mix. Transfer about 40 ml of this solution to a centrifuge tube to which 5 ml washed yeast suspension has been added and from which the water has been separated. Mix yeast and sample well and incubate for 1 hr at 30°C. Proceed as for lactose, using a maltose:iodine ratio rather than a lactose:iodine ratio.

Calculations

For product containing corn syrup solids or corn syrup and nonfat dry milk or calcium-reduced dried skimmilk:

$$\%\ \text{maltose} = \frac{100\ [(D - AE) - (F - AG)]\ [B]}{C}$$

For product containing corn syrup solids or corn syrup but neither nonfat dry milk nor calcium reduced dry skimmilk:

$$\%\ \text{maltose} = \frac{100\ [D - AE]\ [B]}{C}$$

where A = iodine:sodium thiosulfate ratio, B = maltose:iodine ratio, C = milligrams of sample in aliquot (consider the volume of the original sample solution as 200 ml, rather than 210 ml, to take into account the volume occupied by the sample), D = ml iodine added to flask (washed yeast), E = ml sodium thiosulfate required for back titration (washed yeast), F = ml iodine added to flask (acclimated yeast), G = ml sodium thiosulfate required for back titration (acclimated yeast).

$$\%\ \text{corn syrup solids} = (100)\frac{\%\ \text{maltose}}{\%\ \text{maltose in corn syrup solids}} - H$$

where H = correction factor to be applied when nonfat dry milk or calcium-reduced dried skimmilk is absent = 0.4%. No correction factor should be applied when nonfat dry milk or calcium-reduced dried skimmilk is present.

RAPID FAT DETERMINATIONS

A rapid method for determining the fat content of sausage raw materials, sausage emulsions, and finished products is of great practical and economic significance today. A relatively large number of fast methods have been developed. However, it is quite necessary that proper selection of a fat method be made for the particular item to be tested. The time for completing the analysis is very important in some plants, while in others, the sampling technique or the accuracy becomes a limiting factor. Each plant must establish the method best suited for its routine needs.

The sampling for analysis is critical with all the methods. Handling of the material prior to sampling, obtaining a proper size sample, and the handling of the sample must be done in a precise manner.

Rapid fat analyses are usually run on raw materials such as beef and pork trimmings. The methods are usually of two general types: (1) direct, where the fat is separated and weighed or measured, and (2) indirect, where the meat is measured for a characteristic that reflects the fat content.

Direct Methods for Rapid Fat Analysis

Solvent Methods

Solvent extraction methods involve a small test sample and rapid refluxing with ether, chloroform, or some special solvent system, followed by evaporation of the solvent and weighing or measuring the fat residue.

Steinlite Method. The Steinlite method for determining fat is essentially a solvent-extraction procedure in which the solvent and fat are placed in a special cell and a dielectric measurement is made. The fat content is read from a reference chart. High fat levels in a sample require some dilution or adjustment of sample size in order to obtain reliable values. As the solvent odor (*ortho*-dichlorobenzene) is objectionable a ventilation hood is needed for proper utilization of this method.

Babcock Method (Paley). Modified Babcock methods may vary as to sample size and the type of acid digestion used for releasing the fat. A 9- or 30-g sample is most commonly used with a Paley bottle. The Paley bottle has a graduated stem in which the fat can be measured and related to percent fat in the sample. The following modification of this method can be used to determine the fat content of raw materials, emulsions, and finished products. Hydrochloric acid is preferred to sulfuric since it causes less charring, especially when some sugar is present in the sample.

Theory. When analyzing for fat in raw or finished products, the proteins must be broken down to allow the encapsulated fat to separate. Concentrated hydrochloric acid and heat are used to accomplish this. The hydrolysis of proteins should be controlled and carried only to solubilize them, or charring of the meat sample may result. The charred particles can enter into the fat column and interfere with fat determination by blurring the readings. Hydrolysis should be interrupted soon after foaming subsides, by adding water.

Apparatus.

Blender
Magnetic stirrer
Large Paley fat bottle
Water bath
Analytical balance

Chemicals.

Concentrated hydrochloric acid
Dimethyl sulfoxide

Procedure. A 3- to 6-oz meat sample is placed in a blender and chopped at low speed for 15 to 30 sec. (This treatment results in good mixing without excessive emulsifying.)

A 1-oz[1] sample is weighed out in a tared fat bottle. The large Paley bottle uses a 28.4-g (1-oz) sample.

Tighten the glass stopper, add a magnetic stirring bar and approximately 60 ml conc. hydrochloric acid.

Shake the bottle by hand or place it over a magnetic stirrer for 1 to 3 min until the meat is finely dispersed. Raw meat samples require longer and more vigorous stirring. (A fine dispersion of meat in cold acid is a very important step in this procedure.)

Place the bottle in a near-to-boiling water bath, shaking occasionally.

When the foaming subsides or ceases, add 10 ml of hot water and 15 ml dimethyl sulfoxide and mix. Remove the beaker from the source of heat and leave the bottle in the hot bath for an additional 6 min.

Add concentrated hydrochloric acid to bring the separated fat into the calibrated neck of the bottle in such a manner that the cold acid does not mix with the hot acid layer. If the fat layer is not well-defined, add additional dimethyl sulfoxide dropwise to separate the fat from the acid layer.

Read percentage of fat directly from the calibrated stem.

[1]When testing raw meats or if the sample is expected to contain more than 35% fat, take only a ½-oz sample and multiply the reading by 2 to obtain percent fat.

Agreement between the Babcock method and the official method is good. Usually a ±1% variation is observed; the Babcock runs on the high side of the official method for finished sausages and on the low side for raw meat materials. Approximately 30 min is required to complete the test from sampling through reading the fat level in the graduated tube of the Paley bottle.

Test Limitation. The procedure as described should not be applied to the determination of fat in liver or liver sausage. It also does not give satisfactory results with meat products containing milk powder.

This method requires some chemical training but the equipment used is of relatively low cost. Accuracy is good but some care is necessary with sampling and handling.

Indirect Methods for Rapid Fat Analysis

X-Ray Method

The Anyl-Ray equipment has considerable acceptance by the trade. A large sample is used for a test measurement but the sample can be returned to the production line. While the readings can be made in a few seconds, the time for filling the sample cup and handling may require 10 min. The machine functionally operates by the difference in absorption of X rays. The transmitted energy activates a meter that is calibrated for percent fat. A 13-lb sample is used and nontechnical personnel can be trained to run the test. A limitation of the Anyl-Ray method for determination of fat is the fact that it requires fine grinding and good mixing to give reliable results. In general terms, this means the meat must be finely ground through a plate with holes smaller than ¼-in.

Sausage emulsions or finished products with added salt require various corrective factors and do not give satisfactory readings. A 1% accuracy compared to official laboratory methods is claimed by the manufacturer of the equipment.

Specific Gravity Method

The Honeywell digital fat controller measures the fat content of meat samples by compacting the ground meat sample, weighing the compacted mass, and then calculating the specific gravity. A 750-g sample ±25 g is preferred. The specific gravity of lean meat is reported as 1.068, while fat is 0.947. Temperature control and a minimal amount of voids are necessary for good precision. The digital fat controller has become widely accepted and used by the meat industry.

Hot Fat Melt

A number of manufacturers produce equipment for measuring fat content by various hot fat melt procedures. An electric heating unit cooks out the fat from meat samples. The meat is placed on a metal filter plate under the heating unit. The heating unit operates at a high temperature for a short period of time, generally 15 min or less. The fat, which is collected by a funnel and tube arrangement separates into two phases, an upper fatty and lower aqueous layer. The amount of fat is measured in the tube and converted to a percentage.

The method gives only an approximation of fat content, which may be accurate enough for some purposes. However, it is not acceptable where accurate analysis is necessary, and thus, should not be used for analytical purposes.

Summary of Rapid Fat Methods

All the rapid fat methods have some advantages and disadvantages. Each operation should determine the method or methods best suited for its need. The modified Babcock and the Anyl-Ray have reasonably good acceptance by the trade: the Anyl-Ray by its rapidity of obtaining results without skilled technicians, and the Babcock by its versatility, rapidity, and degree of accuracy.

RAPID MOISTURE DETERMINATIONS

The determination of moisture by vacuum drying or other means described by the Association of Official Agricultural Chemists are quite lengthy procedures requiring 12 to 16 hr.

Several rapid methods for meat products are useful if the accuracy required can be achieved. Two of the most commonly used methods will be described in this chapter.

Infrared Moisture Balance

The infrared moisture balance is a unique instrument on which the prepared sample can be weighed directly, dried, and percent moisture read on a rotating scale. The instrument is equipped with a torsion wire to weigh a 5-g sample. Drying of the sample is accomplished in approximately ½ hr by means of an infrared lamp. Reproducibility is good with reasonable accuracy as compared with official moisture determination methods. This method is by far the most rapid.

Sample Preparation. The manner in which meat samples are prepared is of paramount importance. A good homogeneous sample may be difficult to prepare, particularly in the case of raw meat materials, but it is essential. A blender may be quite satisfactory to comminute 50 to 100 g of finely chopped cooked and processed meats. A variable transformer is essential to control the speed of the blender cutting blades. Good chopping and mixing are thus attained without undue maceration of the meat product. Excessive chopping at high speeds can cause fat separation as the meat sample warms up. Also, with the centrifugal forces involved, good mixing is lost. Another problem which can occur when raw materials are being prepared with a blender is that the connective tissues are not well comminuted.

Procedure. A 5-g sample is placed on the disposable aluminum pan designed for use with this moisture balance. The instrument is set at exactly 100%. The meat sample is distributed over the bottom of the pan in such a manner as to balance the pan suspended on a pointed needle wire. The instrument is equipped with a variable transformer with calibration from 0 to 120 volts. A 250-watt infrared lamp is used. The transformer is set at 90 volts. At this setting, charring of the sample during the drying operation does not occur, yet the sample does dry to a constant weight after 30 min. Percent moisture in the sample is read directly from the scale.

Azeotropic Distillation

This method for determining moisture requires special apparatus and a suitable azeotrope for measuring the moisture content of meat products. The time required is usually from 2 to 2½ hr. A large sample can be used, expecially for low moisture content products. Toluene is a common solvent that forms an azeotrope with water. The procedure involves distillation of water from the sample to a collecting tube where the water separates on cooling the azeotrope. The percent moisture can be read from the graduated collecting tube. Excellent results can be achieved with this method; however, the time involved is considerably greater than that required to determine moisture with the infrared moisture balance.

Methods of the Association of Official Agricultural Chemists and the rapid methods have a particular sample size and type of product for which they work best. AOAC methods are generally more accurate and reliable. They carry a mark of authenticity where legal or technical judgments may be needed. The rapid methods most suitable for a particular situation can be selected by a technologist so the overall needs of a plant operation can be met.

Microwave Heating

Although microwave heating units are being sold for moisture determination, these units are not reliable. They show promise but require further development to make these procedures accurate enough to be useful for quality control.

RAPID SALT

Rapid salt analyses are helpful for quality control of cured meats and sausages. The methods are also very useful for checking the salt concentration in curing brines. These methods include the Dichromat salt analyzer, the Quantab chloride titrator, the Volhard filtrate method and the chloride specific electrode.

Dichromat Salt Analyzer

The Dichromat salt analyzer functions on the principle that electrical conductivity varies with salt concentration. The instrument provides a digital readout for salt concentration from 0 to 5%. The salt is extracted from the meat and is measured in the filtrate. The analyzer is standardized using a filtrate of a known salt concentration, usually as determined by the standard Volhard procedure, and the analyzer is restandardized using different filtrates when different products are analyzed, i.e., hams, bacon or sausage. The method seems to agree fairly well with the standard Volhard method for other meat products with the possible exception of bacon. The time required for analysis is comparable to the other rapid procedures for measuring salt, although the filtering process is somewhat longer.

Quantab Chloride Titration

The Quantab chloride titrator consists of a thin, chemically inert plastic strip (about ½ × 3½-in.) to which an absorbent paper capillary column impregnated with silver dichromate is laminated. When the plastic strip is placed in a salt solution, the fluid rises up the column by capillary action. The chloride ions in the fluid react with the silver dichromate ($Ag_2Cr_2O_7$) to produce equivalent amounts of white insoluble silver chloride ($AgCl$), which is titrated against ammonium thiocynate to give the amount of silver chloride, and then is calculated as sodium chloride. The Quantab chloride titrator does not appear to be sufficiently accurate to be useful at this time, although it requires less time for analysis of salt than most of the other rapid methods.

Volhard Filtrate Procedure

In this method the meat product that contains salt is homogenized with water and filtered. Then three 25-ml aliquots of the filtrate are used for determination of the salt content by the standard Volhard method. This procedure gives a salt content comparable to the standard Volhard method for all products, except bacon, for which the value is significantly lower. Time-wise, the Volhard filtrate method has little advantage over the standard Volhard method, and still requires silver nitrate, which is becoming increasingly expensive. Thus, this method is not recommended.

Chloride Specific Electrodes

Development of a relatively new solid-state chloride sensing electrode and a double-junction reference electrode by Orion Research Incorporated of Cambridge, Massachusetts, has allowed adaptation of a pH meter equipped with a relative millivolt function switch for determining the salt content of meat products. Using this switch, the electrode offsets can be corrected with a calibration knob. In this method, the salt is extracted from the meat sample with a reagent containing nitric acid and acetone. The nitric acid prevents interference by the meat proteins, whereas, the acetone helps to solubilize the fat and prevents it from clogging the electrodes.

The chloride specific electrode gives salt values comparable to the standard Volhard method for all products except bacon. From the standpoint of time, the method is faster than most of the other so-called rapid methods for measuring salt content. It can also be easily used for measuring the salt concentration of curing brines. Some processors have attempted to use only the chloride specific electrode without the reference electrode, but results have been unreliable. Thus, using the complete instrumentation is necessary for good results.

RAPID NITRITE

Determination of nitrite by rapid procedures would also be desirable for quality control. Although color reactions show some promise, none of them are useful at this time. The nitrite ion specific electrode is being merchandised and will be discussed briefly.

Nitrite Specific Electrodes

An ion specific electrode for nitrite along with a reference electrode and pH meter connection similar to that described earlier for the chloride specific electrode can be used to determine the nitrite concentration in curing brines. However, the procedure is not satisfactory for measuring the residual nitrite level in meat products, which generally are considerably lower than 50 ppm.

ESTIMATING RAW MATERIAL COMPOSITION FROM LIMITED ANALYTICAL DATA

Small processors often find it difficult to obtain complete analytical information due to limited laboratory facilities. They can, however, usually obtain moisture and/or fat analysis, which can be used to make a reasonably good estimate of protein and/or fat content.

Theory

Skeletal muscle tissue is composed of moisture, fat, protein, and ash. The ash content is usually low, with values ranging from 0.6% in fatty tissues to 2.0% in dense connective tissue (ligaments, tendons, and bones). For most muscle meats, the ash content is about 1.2± 0.5%.

Moisture and protein contents are present in a reasonably constant ratio. Muscle meats from mature animals or aged meat may have a moisture-to-protein ratio (M:P) as low as 3.4, while muscle tissues from young animals (veal or pork) may have a M:P of 3.8 or more. M:P's of 3.8 to > 4 are less common, but occur in heart meat, liver, and some other tissues having high moisture contents.

It is possible to substitute general values for M:P and arrive at an estimate of composition. For these purposes, it can be assumed the M:P ratio for mature beef falls in range of 3.5 to 3.6 and that for most pork from 3.7 to 3.8. Using these values, it is possible to construct tables that give an estimate of fat and/or protein if the moisture content is known. The equation used is

$$100\% = M + F + P + A$$

where M = % moisture, F = % fat, P = % protein, and A = % ash. 100% = M + F + P + 1.2 (assumed ash %).

Then since M = 3.6 or 3.7%, $100\% = M\% + \frac{M\%}{3.6} + F\% + 1.2$

Rearranging the equation:

$$\%\ \text{Fat} = 100 - 1.2 - 1.28\ M\% \qquad \text{or} \qquad \text{Fat} = 98.8 - 1.28\%\ M$$

Estimates Based on Moisture Analysis Only

Example 1. Three samples of young steer beef meat were analyzed for moisture content; values of 68.8, 68.3 and 67.8% or an average of 68.3% moisture was obtained. Unless there is a good reason for believing that the M:P ratio is lower than 3.6, the fat content is estimated as follows:

$$\text{Fat}\ \% = 98.8 - 1.28\ (68.3) = 11.4\%$$

Then

$$\%\ \text{Protein} = \frac{M\%}{M{:}P} = \frac{68.3}{3.6} = 18.97 \text{ or about } 19\%$$

Example 2. It is reasonable to assume a M:P of 3.7 or 3.8 for pork; in this case assume it to be 3.72. The pork trimmings analyzed in triplicate gave an average moisture content of 52.3%. Then substituting the equation becomes:

$$\%F = 98.8 - 1M\% - \frac{1}{3.72}\ M\%$$

$$\%F = 98.8 - 1.27\ (52.3) = 32.4\%$$

$$\%P = \frac{M\%}{M{:}P} = \frac{52.3}{3.72} = 14\%.$$

The only thing that varies in this equation is the moisture multiplier, which is either 1.28 or 1.27. Thus, for very dry appearing meat from cow or bull chucks (M:P = about 3.4), the moisture multiplier should be 1.29. For beef and pork mixes, the value is about 1.28, whereas for fresh young pork or veal, it should be 1.27. Frozen meat which has been thawed and lost large quantities of drip, might be more accurate at a value of 1.28 or greater. Values may range as follows:

Mature animals, low M:P values

$$\% \text{ Fat} = 98.8 - 1.29 \text{ M}\%$$

$$\% \text{ Protein} = \frac{\text{M}\%}{3.45}$$

Average, all skeletal meat

$$\% \text{ Fat} = 98.8 - 1.275 \text{ M}\%$$

$$\% \text{ Protein} = \frac{\text{M}\%}{3.63}$$

Young moist, high M:P meat

$$\% \text{ Fat} = 98.8 - 1.26 \text{ M}\%$$

$$\% \text{ Protein} = \frac{\text{M}\%}{3.8}$$

The errors in assuming a value of 1.2% for ash may be up to 0.5%, while errors of up to 1% or more could result from the specific M:P assumption. Those using the estimates should recognize the possibility of such errors.

Estimates Based on Both Fat and Moisture Analysis

More precise estimates of protein are possible when accurate analysis of both moisture and fat are available. Then it is possible to adjust the assumed percentage of ash to reflect more accurately the meat being utilized, using lower values for meat high in fat content or higher values for meat high in tendons or sinews. Then the equation becomes

$$\% \text{ Protein} = 100 - \text{estimated ash}\% - \text{M}\% - \text{F}\%$$

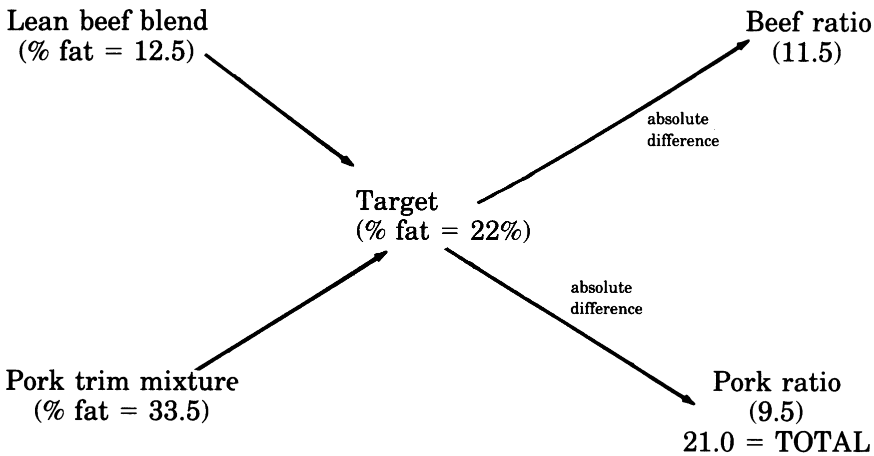
Federal regulations permit up to 3% or more of ice or added water in processing semidry fermented sausages. In checking these products for compliance, it is appropriate to use a moisture multiplier of 1.265, which is based on an M:P ratio of 3.78.

USING FAT CONTENT TO AID IN FORMULATING SAUSAGES

Usually the processor has a target percentage of fat or lean for both the raw and finished product. By having analytical data on the composition of the raw materials, it is possible to determine the amount of the raw materials needed to reach the compositional goals. Meats of either known or estimated composition may be blended to give a fatter or a leaner blend, which may be mixed to give the final target fat content.

Use of Dilution Square Technique

If one has two batches of meat differing in fat content, it is possible to use the dilution square technique to reach the amount of each mixture that is needed to yield the final desired fat content. For example, assuming the target is 22% desired fat content for making a 500-lb batch of summer sausage from a raw beef blend of 12.5% fat and a pork trim mixture of 33.5% fat content, the dilution square technique can be applied as shown below:



The beef ratio is obtained by subtracting the desired fat content from the fat content of the pork mixture, 33.5% − 22.0% = 11.5 lb of beef.

The pork ratio is obtained by the same technique, i.e., the difference between the percentage fat in the beef mix (12.5%) and the desired fat content (22%) or 22.0 − 12.5 = 9.5 lb pork. The dilution square shows that to compound a mixture containing 22% fat, a ratio of 11.5 lb of beef to 9.5 lb of pork is needed. Thus, each 21 lb of meat should contain 9.5 lb of pork and 11.5 lb of beef. Since a total of 500 lb is needed to make up a single batch, the multiplier = 500 ÷ 21 = 23.81

$$\begin{aligned} 23.81 \times 11.5 &= 273.8 \text{ lb of beef} \\ 23.81 \times 9.5 &= \underline{226.2} \text{ lb of pork} \\ & \quad\ 500.0 \text{ lb total} \end{aligned}$$

or, expressed another way,

$$\frac{11.5}{21} = \frac{\text{beef amount}}{500} \text{ and } \frac{9.5}{21} = \frac{\text{pork amount}}{500}$$

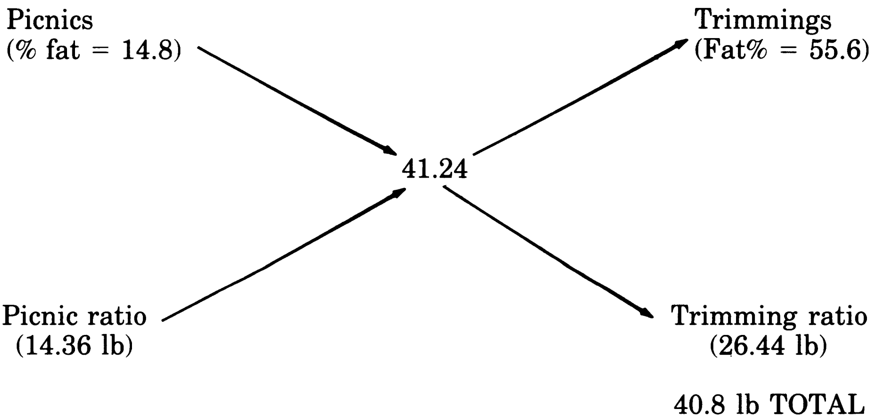
Adjustments for Added Water

Fresh sausage with 3% added water can be adjusted for water content. For example, to make 750 lb of finished sausage with 40% fat in the final product prepared from boneless picnics (14.8% fat) and 50/50 pork trimmings (55.6% fat), the amount of the blend and percentage of fat prior to ice addition is calculated as follows.

$$750 \text{ lbs} = 3\% \text{ ice} + 97\% \text{ meat or } 727.5 \text{ lbs of meat}$$

which must contain 40% fat or (0.4 × 750 lb) 300 lb of fat, which comprises 41.24% of the total.

Then by applying the square method,



Then,

$$\frac{727.5}{40.8} = 17.83 \text{ multiplier}$$

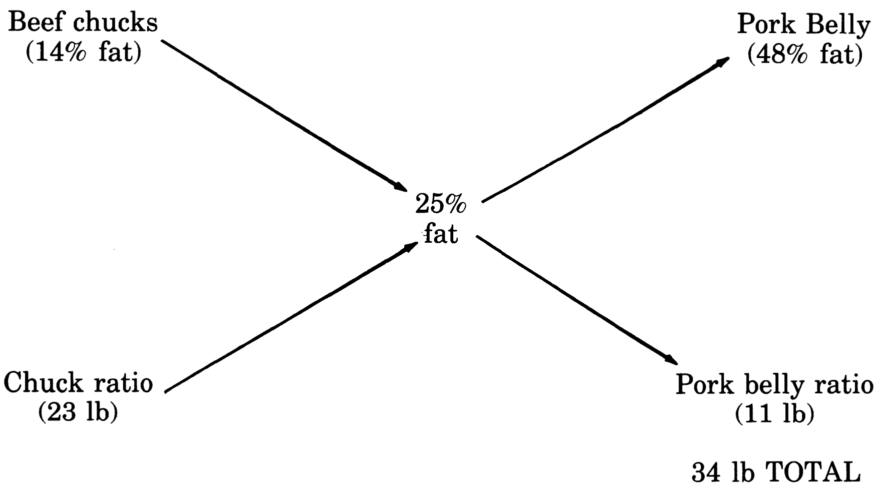
$$17.83 \times 14.36 = 256 \text{ lb picnics}$$

$$17.83 \times 26.44 = \frac{471.5 \text{ lb trimmings}}{727.5 \text{ lb total}}$$

$$\text{ice} = 3\% \text{ of } 750 = 22.5 \text{ lb}$$

Adjustment for Cooking-Drying Shrinkage

Adjustment for shrinkage during processing is based on previous experience and gives a yield estimate. For example, assume that one wishes to produce a fermented dry sausage with a target fat content of 28.8%, which will shrink an estimated 13.3% during fermentation and heating-drying. Adjusted for shrinkage, it will give a final yield of 86.7%. If it is manufactured from 1050 lb of a raw meat blend composed of USDA Choice grade beef chucks that contain 14% fat and pork belly trimmings with 48% fat, then one adjusts for shrinkage as shown below. Then, 1050 lbs × 0.867 = 910.3 lb of sausage with 28.8% fat or 262.18 lb of fat. The 262.18 lb fat equal 24.97% of 1050 lb or about 25% fat is needed in the raw blend.



Then,

$$\frac{23}{34} = \frac{\text{chuck amount}}{1050} = 710.3 \text{ or about 710 lb of beef chucks,}$$

and

$$\frac{11}{34} = \frac{\text{belly amount}}{1050} = 339.7 \text{ or about 340 lb of pork bellies; or 1050 lb total.}$$

ROUTINE ANALYTICAL LABORATORY FOR MEAT PRODUCTS

The laboratory requires a 10 × 15 ft area for conducting the analytical procedures. This space should have suitable work benches and room for facilities such as a fume hood, water, gas, electricity, compresser, air, a vacuum line, good drains or sewers, and possibly some type of air conditioning unit. An office space of 10 × 10 ft is desirable and should adjoin the laboratory.

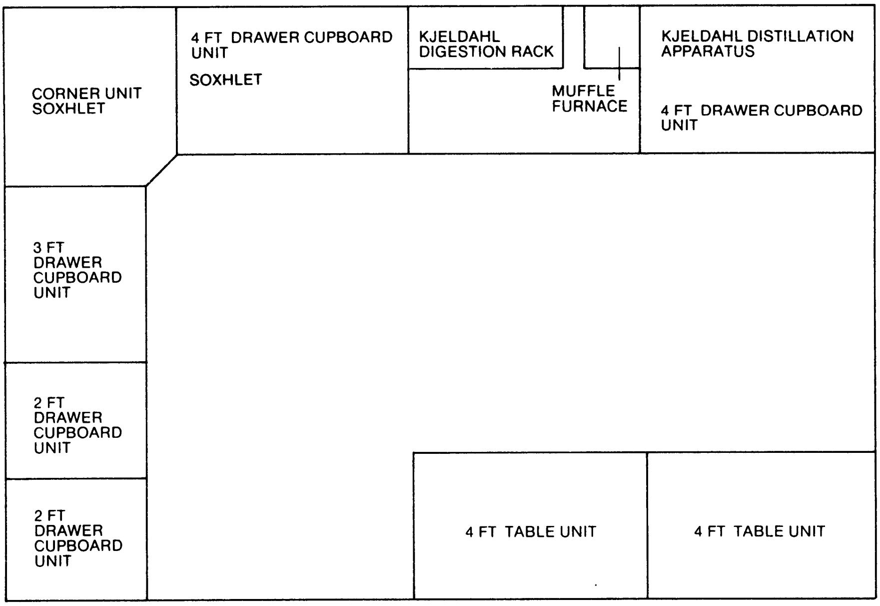


FIG. 16-1. Analytical laboratory layout.

Estimates on the costs of the laboratory space and equipment can be obtained through a reliable laboratory equipment supply house working in cooperation with a competent architect. The laboratory furnishing should include adequate cupboards, 2-ft sink, tables, hood, Kjeldahl digestion rack and fume duct, muffle furnace, 6 unit size Soxhlet extraction apparatus with heaters, Kjeldahl distillation apparatus, vacuum oven and water aspirator, electric meat grinder, torsion balance (2-mg sensitivity), pH meter, colorimeter, hot plate, analytical balance, spectrophotometer, Kjeldahl flasks, Erlenmeyer flasks, assorted beakers and test tubes, burettes (50 ml), porcelain crucibles, and pipettes.

The costs of reagents, furnishings, laboratory space and glassware are part of the investment necessary for setting up a laboratory. With increased enforcement of meat inspection and labeling regulations, few meat processors will be able to survive and grow without an efficiently run laboratory for quality assurance. A general layout for a small laboratory is shown in Fig. 16.1. For convenience and ease of operation the laboratory should be located near quality control or production control areas.

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17

Other Methods of Processing

Although canning, curing, and sausage production comprise the major meat processing procedures, several other methods are being used by the meat industry. Obviously, some of the processing procedures are used primarily for fresh meat, but are considered in this text because they are closely interrelated. Many of those mentioned are still in the developmental stages and could well become important within the next few years. New methods of processing and new-product development are often inseparable and will be discussed together.

Industry, universities, and governmental agencies are all concerned with development of new processes and new products, which is essential to the growth and viability of the meat industry. Processing methods must be constantly reviewed and updated by research and development groups. But even more important, these groups also must consider other promising ways of more effectively and efficiently processing meats. Procedures generally require approval of either the Food and Drug Administration or Food Safety and Inspection Service before adoption by the industry. Even minor changes in processing procedures must be carefully considered because of implications to human health and nutrition. Thus, development of new techniques for processing requires careful experimentation and accumulation of data before these techniques can be instituted at the plant level.

PURPOSE OF DEVELOPING NEW METHODS

There are a great many reasons for development of new processing methods, among which are more rapid production, economy, decreased spoilage, greater variety of products, greater convenience, lower labor costs, and increased utilization of by-products. Many of these purposes overlap and are closely related, but each is also important itself.

Rapid Processing

Reduction of inventory permits a greater turnover of investment in raw materials. Usually, volume is indicative of profit, although this is not always true; in fact, a greater volume of product can also result in a larger loss if margins are negative. Thus, speedier processing is important only if the final product is profitable. There are many examples where faster processing has played an important role, such as changing from dry-cured to stitch-pumped bacon, or from batch to continuous processing of frankfurters. Although rapid processing results in greater turnover of capital outlay and investment of less funds in the same amount of product, these advantages must be balanced against disadvantages, one of which is often a decrease in quality. For example, stitch-pumped bacon can be produced much faster, but dry-cured bacon brings a higher price. Consequently, many small operators have been able to profit by production of quality products.

Speeding up processing has distinct advantages in reducing inventories and hence capital outlay, but should be considered in all its ramifications before any new processing procedure is adopted. Furthermore, the importance of maintaining quality while altering processing procedures should not be overlooked. Reduction in quality, which often results from increasing output, is very difficult to compensate for by increasing speed of production.

Economy

Economy is usually achieved by a variety of procedures and must be carefully considered at all phases of production. The success of any process will ultimately depend on its being economically feasible. Nevertheless, one should not lose sight of the fact that even economical processes are not always self-supporting. New developments almost always require some subsidization during their early phases and are seldom profitable immediately. However, research and development personnel must be able to visualize profitable production and project the costs of production and ultimate profits from any new process or product.

Reduction in Losses from Spoilage

Decreasing spoilage can lead to more profitable production, providing, of course, that it can be achieved economically. Knowledge of the causes of spoilage and their control is not only important to existing operations but also to development of new products and processes. The industry has a great deal of responsibility for prevention of spoilage, as well as for food safety and freedom from food poisoning.

New Product Development

Product development is of utmost importance to the meat industry. Although development of new products or even changes in old products are often expensive, they pump new life into the industry and are necessary to keep it competitive with other foods. New product development requires both foresight and imagination, which are obviously key elements to profit. On final analysis, however, new product development is only a beginning; few products ever reach production, and even fewer are successful. Nevertheless, new products provide diversity and are essential to success.

Convenience

Convenience foods, which are fully or partially prepared, are a most important element in new-product development. The consumer has become increasingly aware of convenience foods as more and more women are working outside the home. Speed and ease of preparation have become particularly important and have demanded more processing, and more technology and labor, the costs of which can be passed on to the consumer. Producers of convenience items must always exercise very careful control of processing techniques to maintain quality of the final product.

Reduction of Labor Costs

Lower labor costs are often an important consideration in production of new products or in altering existing processing procedures. Continuous processing of frankfurters was developed to make more effective use of labor and to streamline the manufacturing process by mechanization. Replacement of batch processing by an on-line method has distinct advantages in labor costs, even though the initial outlay may be high. Streamlining and mechanization of meat processing will no doubt continue. Decisions should be arrived at first by considering the alternatives, including quality of the finished product, and then the economics involved. Obviously, any process alteration that will reduce labor costs has distinct advantages, other things being equal, because labor costs usually comprise the major portion of the cost of processing.

Increased Utilization

Finding new uses for by-products has long played an important role in meat processing. In fact, sausage originated as a consequence of attempts to utilize more effectively by-products of slaughtering and cutting. Forward-looking research and development groups are not satisfied with mere disposal of by-products, but are constantly seeking better utilization of them.

Utilization requires imagination and foresight. One cannot be satisfied with traditional uses of by-products, but must constantly consider new uses and new approaches. The meat-packing industry today faces the problems of water and air pollution. Although dumping of plant effluent into streams and burning of waste products seemed simple solutions to disposal of packing house wastes, today meat-packing companies have either installed their own waste-treatment facilities or utilize those of the community in which the plant is located.

OTHER METHODS OF PROCESSING

The methods reviewed herein are not the only promising developments in meat processing. However, they do include the more recent methods in use, including some which are being used commercially. Other procedures discussed are still being investigated commercially and show some promise.

Hot Processing

Hot processing is a term used to describe the processing of meat before the body heat has been removed by cooling. It has the obvious advantage of energy savings since it is not necessary to chill the meat both before and after processing. The hot meat also has the advantage of better emulsification of fat in the blending of sausages, curing ingredients are more readily taken up, as well as in improvement of yields. It also results in a faster turnover with reduction of inventories. The latter advantage has played a major role in the hot processing of whole hog sausage, where hogs are often killed and made into sausage the same day.

Hot processing, however, also has some disadvantages. The meat is soft and harder to cut and handle. Sometimes this problem is partially overcome by chilling or holding for a few hours before cutting and further processing. There is also some evidence suggesting that microbial counts are higher in hot processed meat. This does not appear to be a serious problem if the meat is processed rapidly and quickly chilled while maintaining good sanitary practices. It can result in spoilage, however, if proper precautions and good quality control are not practiced.

Hot processing has grown in popularity since development of electrical stimulation, which will prevent cold shortening and the associated toughening of prerigor meat that is exposed to cold temperatures. Electrical stimulation of prerigor meat lowers the pH rapidly by breaking down the reducing sugars and glycogen so that rigor mortis occurs much earlier. Adenosine triphosphate (ATP), which provides the immediate source of energy for both cold shortening and thaw rigor, is dissipated by electrical stimulation. Therefore, prerigor meat can be rapidly frozen without cold shortening or development of thaw rigor, which is characterized by massive shortening and excessive drip losses on thawing of meat that is frozen prerigor. Thus, electrical stimulation of carcasses and/or sides has proved to be extremely useful for accelerating the development of hot processing.

Hot processing both with and without electrical stimulation appears to be gaining in importance. The reduction in meat inventories and the increased product yields, which are often 0.5–2.0% higher than for meat processed after chilling, are likely to provide incentives above and beyond those from increased energy savings.

Freeze-Drying of Meat

Although dehydration can be achieved by either freeze-drying or heat dehydration, the latter method is not being used for meat, and thus will not be discussed. Freeze-dehydrated meat is, however, being manufactured and marketed commercially. The largest portion of dehydrated meat now being manufactured is found in dehydrated soup mixes, where meat is only one, although a most important, ingredient. Dehydrated meat is also available for campers or hikers where light weight and stability are essential. Even though the total market volume of dehydrated meat is small, its advantages will probably continue to create a growing demand for these products in special markets.

The exploratory work on development of dehydrated meats has largely been under the auspices of the armed forces. Light weight and the lack of a need for refrigeration are major advantages of dehydrated meats for military personnel. These same factors have also contributed to the demand for freeze-dried products by the civilian population.

The method used for freezing meat that is to be dehydrated is just as important as the drying method. Slowly frozen meat produces a better-textured freeze-dried product than that frozen rapidly. Rapidly frozen meat rehydrates more slowly and is tougher and poorer in texture. Meat to be freeze-dried should be frozen slowly, preferably at about 15°–25°F.

The dehydration process is accomplished by sublimation, which is the transfer of ice from the product to the atmosphere in the form of vapor. Each pound of ice sublimed requires 1200 BTU's. During dehydration, heat transfer occurs both within the product and outside or away from the product. Transfer of heat within the product during freeze-drying occurs in three ways: (1) by sublimation of the ice layer, (2) by evaporation or desorption of the adsorbed water in the ice-free layer, and (3) by elevation of the dry layer temperature. Heat transfer at the food surface occurs by a combination of radiation and convection, resulting in the removal of moisture from the surface of the product.

In addition to application of heat or energy to facilitate moisture removal during freeze-drying, establishment of a vacuum also plays an important role in moisture transfer. Although the vacuum greatly speeds up drying, too low a pressure is expensive to produce and may even slow down the drying rate.

There are a number of different types of freeze-dryers available. Early models contain fixed plates; more recent types are arranged so the freeze-drying plates can be adjusted relative to each other, and are used almost exclusively for pressure—contact freeze-drying. This method is usually called vacuum contact drying (VCD) or accelerated freeze-drying (AFD). Basically, the method increases heat transfer by bringing the plates into close contact with the food. An expanded metal grid is placed between the plates and the food to allow the vapor to escape and to increase penetration of heat into the food during contact drying. This design makes it possible to speed up the drying rate or lower temperatures, while still achieving the same rate of moisture removal.

Optimum residual moisture content varies with the food. Meat, fish, and poultry are shelf-stable at a level of about 3.5% moisture at 72°F. There appears to be little advantage in levels lower than this, although 2% moisture is often advocated. The latter value is a hold-over from freeze-drying of pharmaceuticals and biological materials and does not apply to foods.

Organoleptic acceptability of freeze-dried meat is most often limited because of toughness and lack of juiciness, which is apparently due to denaturation of actomyosin. Another serious problem is development of browning and loss of natural meat color. This appears to be due to both carbonylamino browning and oxidative browning of the meat pigments. The end result is not only poor color but also undesirable bitter flavors that make the meat unacceptable. Many of these changes can be prevented by proper storage, as will be discussed later. Poor acceptability can also result from the enzymatic activity of residual enzymes in the tissues. Although residual enzymatic activity is not commonly a problem in dehydrated meat, poultry, or fish, it can cause some oxidative changes in the pigments. It can usually be prevented by heat-inactivating the enzymes by precooking before freeze-drying.

Storage of freeze-dried meat is an important consideration. Since freeze-dried meat becomes rancid rapidly in the presence of oxygen, it must be packaged in a vacuum or under an inert gas to avoid oxidative deterioration. Freeze-dried meat is normally packaged in nitrogen, using a high-grade packaging material. If properly processed and packaged in an inert atmosphere, dehydrated meat is shelf-stable and can be held for long periods without deterioration.

Costs of distribution of dehydrated meat are less than those of frozen meat. In fact, they appear to be about the same as the costs of distributing canned foods.

Dehydrated meat shows considerable promise as a shelf-stable food item. Although spectacular growth of the market for dehydrated meat is not likely, demand will probably continue with slow but continuous growth.

Intermediate-Moisture Meats

The term "intermediate-moisture" has been used to identify a heterogeneous group of foods, which resemble dry foods in that they are resistant to bacterial spoilage but contain too much moisture to be considered as dry foods. Generally, their moisture content is of the order of 20–30%, yet they can be held without refrigeration. Among the traditional intermediate-moisture foods are air-dried figs and dates, prunes, marshmallows, soft candies, jams, jellies, fruit cakes, and a variety of meat products such as Country-style cured ham, jerky, pepperoni, and other dry sausages.

Although the principles underlying the preparation of intermediate-moisture foods are well known, recent interest in development has been stimulated by practical application in producing intermediate-moisture pet foods. Several recent patents have been granted in this area and intermediate-moisture pet foods are now available in a variety of forms.

Stability of Intermediate-Moisture Products. Although intermediate-moisture foods are relatively soft, easily masticated, and have a moist feeling in the mouth, they are microbiologically stable. The more recent developments in this area have been made possible by commercial availability of antimycotics, which suppress the growth of yeasts and molds.

Even though intermediate-moisture food products are microbiologically stable, they are more susceptible to the browning reaction than dry foods. They are, however, less susceptible to oxidative deterioration. Unless suitable precautions are taken to inactivate the indigenous enzymes, they are also liable to a variety of enzymatic alterations.

The basic principle underlying microbiological stability of intermediate-moisture products is the reduction in water activity (a_w), which prevents spore germination and microbial growth. For the purposes of this discussion, water activity may be defined as the ratio of the vapor pressure of water in the food (P) to the vapor pressure of pure water (P_0) at the same temperature. The formula for expressing this relationship is $a_w = P/P_0$. Temperature can be disregarded for normal mesophilic food spoilage organisms, since their a_w is practically independent of temperature.

Although safety from microbiological spoilage depends on the food, its previous treatment, the organisms present, handling, storage, and a variety of other conditions, pet foods with an a_w of approximately 0.85 have an excellent record for stability under market conditions. Thus, meat items properly processed and packaged would normally require an a_w of 0.85. This assumes, of course, that antimycotic agents are used.

Production of Intermediate-Moisture Foods. Development of intermediate-moisture foods has been pioneered by researchers at the U.S. Army Natick Laboratories, who have developed several such products for military feeding. They have shown that several additives can be utilized for lowering the water activity of the products to produce intermediate-moisture foods (Brockmann 1970). The most common compounds used for this purpose are sugar, glycerol, and salt. All three of these compounds have certain disadvantages, so a combination is most commonly recommended for achieving the desired moisture level.

To produce the most acceptable meat items in the intermediate-moisture range, experience has shown that the desired a_w can best be achieved by equilibrating the food in an aqueous solution of glycerol, salt, and antimycotics. The food is immersed in a solution of the proper concentration to give the desired a_w and also the proper level of antimycotic. It is then cooked in a water bath at 203°–212°F.

Table 17.1 shows a number of equilibrating solutions used in making different meat products. The equilibrating medium is variable, depending on the composition of the original product and its water content. Similar equilibration procedures have been successfully applied not only to beef, pork, and sweet and sour pork, but also to lamb, ham, tuna, and chicken. It has also been used in producing a number of meat casserole items, including beef stew, creamed tuna and noodles, chicken a la King, and Hungarian goulash. The method also appears to be suitable for a variety of other meat products.

Except for a slight recognizable sweet taste, foods at an a_w of 0.80 to 0.85 have normal flavor, aroma, and texture. The flavor can be further improved by addition of soup or gravy bases to the immersion or equilibration medium.

The future appears favorable for intermediate-moisture foods, al-

TABLE 17.1. Composition of Equilibration Solution for Intermediate-Moisture Meat Products

	Products		
Components	Pork	Beef	Sweet & Sour Pork[a]
Glycerol	45.6	87.9	25.00
Water	43.2	—	15.00
Salt	10.5	10.1	2.59
Sucrose	—	—	11.84
Potassium sorbate	0.7	—	0.30
Sodium benzoate	—	2.0	—
Catsup	—	—	23.84
Vinegar	—	—	13.50
Starch hydrolyzate	—	—	4.22
Corn starch	—	—	2.30
Monosodium glutamate	—	—	1.15
Mustard powder	—	—	0.23
Onion powder	—	—	0.02
Garlic powder	—	—	0.01

Source: Brockmann 1970
[a] a_w = 0.85

though to date their development is still in the experimental stages. Their stability appears excellent and the ease of storage and handling should make intermediate-moisture meat products a valuable adjunct to present methods of meat preservation.

Preservation of Meat with Antibiotics

Soon after antibiotics became accepted by the medical profession as a means of controlling bacterial infections, their use in extending the shelf-life of fresh meat was suggested.

Selection of an Antibiotic. Since a variety of spoilage organisms are normally present in meat products, it is best to select a broad-spectrum antibiotic. The two most common and cheapest of these are oxytetracycline and chlorotetracycline, both of which have been utilized on meat. However, other broad-spectrum antibiotics may also be equally effective in controlling microbial growth. Other special antibiotics with a narrow spectrum may also be used to control food spoilage that is due primarily to a specific microorganism. A combination of antibiotics may prove to be the most effective under normal conditions.

The second factor to be considered is the matter of cost, assuming the antibiotics available are of equal value for controlling bacterial growth.

Application of Antibiotics. Antibiotics can be applied to meat readily by using sprays and dips. Generally, the greatest level of contamination is on the surface, so that spraying and dipping are effective.

Where deep tissue spoilage occurs, spraying and dipping are not effective, and infusion through the arterial system, as is done in pumping hams, is preferable. The latter system can be applied to cuts in which the arterial system is intact, such as beef rounds or pork hams, but cannot be used on many other cuts. The entire carcass can also be infused with antibiotics. This technique has been used effectively by Weiser *et al.* (1954). These investigators normally used the carotid artery for injection of the antibiotic solution.

Still another method of using antibiotics is that of injecting the animal prior to slaughter. Antemortem intramuscular injection 30 min before slaughter gave just as good results as spraying or dipping of the cuts from the carcass.

Levels of Antibiotics. Adequate control of spoilage can be achieved by spraying or dipping with 20 ppm of oxytetracycline. Antemortem injection at a level of 0.8 mg per pound of live weight gave good control of spoilage. Infusion of chlorotetracycline into either intact beef rounds or the entire carcass was effective at a level of 55 ppm. Exact levels should be determined in cooperation with the manufacturers.

Present Applications. Although antibiotics were widely used on cut-up poultry a few years ago, this was often a substitute for cleanliness and good sanitation. As a result, it has been abandoned, and proper processing techniques have achieved essentially the same shelf-life. It must be emphasized that antibiotics should not be considered a substitute for good sanitary practices but only as a means of extending the shelf-life of a relatively good product.

Antibiotics have also been used on red meats. Attempts were made to use them on carcasses shipped from New Zealand and Australia to England. However, the uncertainty of ship movements and delays in loading suggested that the use of antibiotics was not feasible under current management practices. However, better scheduling and more reliable shipping could overcome many of these problems and make antibiotics applicable to the meat industry. Currently, antibiotics are not approved by federal meat inspection regulations for use in meats in the United States.

Other Problems with Antibiotics. The most serious problem with antibiotic preservation of foods is the matter of cross-resistance transmitted from one bacterial species to another. This means not only that bacteria may become resistant to antibiotics, but (even more important) that a group of bacteria with increased resistance may develop. Although the theory of cross-resistance is still being investigated, additional usage of antibiotics should not be permitted until more information has become available.

Preservation of Meat by Irradiation

Irradiation of foods is not a new process; it has been used in production of vitamin D-enriched milk for many years, as well as in controlling microbial growth during the aging of beef. This process uses ultraviolet radiation. When the carcasses and the radiation sources are arranged properly to permit all surfaces to be exposed, microbial growth is inhibited and the aging room temperature can be increased to about 65°–68°F for a period of approximately 48 hr, resulting in rapid tenderization. The process is patented and beef produced by this method is trade-marked "Tender Ray".

Perhaps the greatest use of this process in the future will be its application to the aging of prerigor meat, especially beef. The endogenous enzymes act on the myofibrillar and connective tissue proteins while the temperature is still high, and at the same time would control microbial growth. It could be applied to carcasses that have been electrically stimulated or to unstimulated carcasses as desired.

Shortly after the conclusion of World War II, the U.S. Atomic Energy Commission became interested in exploiting peaceful uses for atomic radiation. The use of irradiation as a means of preserving foods, and especially meat, was one of those applications. Although both β- and γ-

rays were applicable to destruction of food-spoilage organisms, β-rays possessed only a limited ability to penetrate and were suitable for only thin cuts of meat or surface radiation. Consequently, γ-rays have been used mainly for irradiation of meat products. Irradiation can produce either a pasteurized product or a commercially sterile product.

Levels of Irradiation. The basic unit of measuring irradiation is the rad. Commercially sterilized meat has been calculated to require about 3.2 million rads. Pasteurization, of course, is achieved at much lower levels. Meat will require from 50,000 to 250,000 rads. The exact level for pasteurization will depend on how long the storage life is to be extended and also upon the level of flavor changes that will be tolerated. However, in actual practice about 75,000 to 150,000 rads are used to pasteurize meat products.

Commercially Sterile Meat Products. Generally, irradiation is done with cobalt-60 or spent fuel rods, although there also are other suitable methods. Two major problems have been encountered with irradiated meat: (1) immediate flavor changes due to irradiation per se, and (2) flavor and textural changes during the subsequent storage.

Irradiated meat has been described as having a wet-dog or chicken-feather aroma. This is the main reason irradiated meat has not been a success. The objectionable aroma and flavor are closely related to the level of irradiation. Recently, some progress has been made in solving this problem by using low-temperature irradiation. If meat is irradiated at temperatures of −50°F or below, there is decided improvement in flavor and odor. This suggests that some of the chemical changes are temperature-related and can be prevented by low temperatures. Studies at the U.S. Army Natick Laboratories have shown that low-temperature irradiation has real promise for production of commercially sterile meat products.

The flavor and textural changes that occur during storage of commercially sterile meat are due to enzymatic activity, which can largely be prevented by destruction of the enzymes either before or after irradiation. Heating to inactivate the enzymes appears to be the most effective method for preventing enzymatic changes. An internal temperature of 150°–155°F is necessary for enzyme inactivation.

Shelf-stable meats produced by sterilization have found their greatest use for military feeding. With improved flavor and texture, it is also possible that irradiated meat may become available to other consumers.

Pasteurization of Meat by Irradiation. Although flavor problems are also encountered in irradiation-pasteurized meat, the extent is much less than for the sterile product. One selects a level that will extend the shelf-life but minimize flavor deterioration due to radiation.

Since pasteurizing irradiation is used for extension of shelf-life and could be used in centralized packaging of fresh meat, the problem of color is of primary importance. Some work has indicated that color and even flavor can be improved by using polyphosphates. If the meat is packaged in vacuum, the oxymyoglobin will be reduced to myoglobin. Then, in the presence of polyphosphate and upon exposure to air, the myoglobin takes up oxygen readily and forms the light red pigment, oxymyoglobin.

The use of irradiation pasteurization of meat has been permitted on an experimental basis to determine its feasibility in centralized packaging. Since the storage life of fresh meat can be easily extended to 18 to 21 days by this process, it is potentially an important development.

Both commercially sterile and pasteurized irradiated meat products are still in the experimental stages. However, it seems probable that one or both of these methods will be used in the future.

Irradiation of Cured Meats to Replace Nitrite. Considerable research has been carried out using irradiation of cured meats to reduce the amount of nitrite needed. This treatment is effective in controlling *Clostridium botulinum* in cured meats, which is the cause of botulism. Although meat cured without nitrite and irradiated is safe to eat both from the standpoint of freedom from *C. botulinum* and other pathogenic microorganisms and does not contain *N*-nitrosamines, irradiation does not prevent lipid oxidation or impart cured meat flavor and color to the products. Thus, low levels of nitrite and nitrate have been used in combination with irradiation to produce acceptable cured meats.

It has been demonstrated that low levels (25–40 mg/kg) of sodium nitrite in combination with irradiation produces satisfactory ham, bacon, and corned beef. Studies have shown that the cured color in cured irradiated ham containing 25 mg/kg of sodium nitrite is not stable during subsequent storage. However, addition of 25 mg/kg of sodium nitrate plus the nitrite produced a shelf-stable product. There is no evidence that meat cured with low levels of nitrite and nitrate followed by irradiation is toxic in any way.

If it should be shown that reduction to low levels or complete elimination of nitrite and/or nitrate is desirable in curing of meat, irradiation could offer a viable alternative. Complete elimination of nitrite, however, would give a product lacking the characteristic cured meat color and flavor.

Microwave Processing

Microwave heating of foods is not new, but most of the work in this area has occurred since World War II. The method is based on the fact that foods are composed of both positively and negatively charged particles, but as a result of the balance between the two, are electrically neutral. Thus, a food is nonconducting or dielectric. When placed in an electromagnetic field, the charged asymmetric molecules of the dielectric food are driven first in one direction and then in another in an attempt to align themselves with the positive and negative poles. The movement back and forth creates intermolecular friction, which produces heat within the food.

Of the frequencies that have been allocated for industrial, scientific, and medical uses, 915 and 2450 MHz have been utilized most often. Several devices have been developed for food use including both batch-type and continuous processing equipment.

Microwave processing of food is still in its infancy, but has the following three advantages: (1) it rapidly provides uniform energy throughout the product without the limitations of normal heating, such as losses by conduction and convection and surface crust formation; (2) microwaves have only one effect on a food, that is, the effect of heating; and (3) during microwave processing, the amount of heat absorbed is strictly a function of frequency and of the dielectric loss characteristics of the food.

Microwave heating has been used for thawing of frozen pre-cooked meals for institutional use and for thawing other frozen foods. Microwaves also appear to have definite possibilities for supplying the energy needed for sublimation of ice in production of freeze-dried meats.

Microwaves are not only useful for cooking but also have been shown to be effective in sterilization of different foods. It appears to have special possibilities for destruction of foot-and-mouth disease viruses in meat, and at the same time avoiding development of cooked meat flavors. Although much remains to be done in application of microwave energy to foods, it is a promising field and seems to have application in meat processing.

Recently, the effectiveness of microwaves in destroying pathogenic bacteria and trichinae has been questioned. Failure to destroy these pathogens is related both to the short dwell time at the final temperature and to cold spots in some microwave ovens. Manufacturers of microwave equipment will no doubt take steps to eliminate such problems. However, meat processors should be aware of the possibilities and be certain that processing with microwaves is adequate.

Freezing as a Means of Preserving Meat

The present discussion is not intended to be a complete discussion of freezing, but merely an introduction. Those wishing additional information on freezing and its application to meat processing should refer to the bibliography.

Freezing is an excellent method of preserving meat and causes little adverse change if done properly. Fresh meat and frozen meat after thawing are extremely difficult, if not impossible, to tell apart. Nevertheless, frozen meat is often inferior because proper precautions in preparation, freezing, and storage are not taken into account.

Preparation for Freezing

Freezing of meat is often practical as a means of storing surplus meat for later use. It is a common practice for slaughterers and processors to freeze meat during peak slaughtering or production to either sell or process later. Freezing also provides a means of reaching distant markets, where an otherwise perishable product would not be available. It has become particularly important in Australia, Argentina, Uruguay, New Zealand, and other meat-exporting countries.

Preparation for freezing is most important, since freezing does not improve the raw product. The best one can hope for is that the meat will be nearly as good when it comes out of the freezer as when it went in. Thus one should take every precaution to see that any product to be frozen is in very good condition at the time of freezing. Generally, this means the meat should have passed through rigor mortis and be aged to reach its optimum tenderness without any loss in quality. For best results, meat should not be frozen until at least 48 hr after slaughter, and preferably only after 5 to 7 days. The recent application of electrical stimulation, however, has allowed the freezing of prerigor meat without development of two problems that were previously encountered: (1) cold shortening with its attendant toughening, (2) thaw rigor with its associated shortening and excessive drip losses.

In general, excessive amounts of bone and fat should be removed prior to freezing. Any contaminated or dirty areas should also be removed.

Packaging is probably the most important single step in preparing a good quality frozen product. Only high-grade packaging material should be used, and it should be carefully applied in order to protect the frozen product from freezer burn and fat oxidation. Poor packaging is probably the biggest single problem affecting frozen meat, although improper storage conditions may rival it and confuse the picture. Not only should the package be impermeable to air and moisture, but it should fit closely the contour of the meat. Dead spaces within the wrapper can result in freezer burns just as serious as those arising from torn or poorly applied wrappers.

Freezing Process. The freezing process should be fast enough to prevent deterioration. If freezing is too slow, bacterial growth will continue and quality will decline. Some controversy exists as to the importance of rapid freezing, but all agree it should be fast enough to prevent any deterioration in quality. Temperature alone does not necessarily govern the rate of freezing; the rate of air movement or contact with the refrigerating medium has an even greater effect on the speed of freezing.

There do not appear to be any disadvantages associated with rapid freezing aside from costs. Therefore, freezing at a rapid rate seems best. A temperature of 0° to −20°F is quite satisfactory, if the heat can be removed from the product at a reasonably rapid rate. If the temperature remains too high for extended periods of time, spoilage can occur.

Freezer Storage Conditions. Storage conditions have a profound influence on the quality of the final product. Next to the quality of the original product and method of packaging, freezer storage conditions have the greatest effects on the quality of the frozen meat. Fluctuations in temperature accelerate freezer-burn and cavity ice formation, both of which have the same final effects. Losses of weight during freezing are caused by variations in temperature as well as by poor packaging. High temperatures and particularly fluctuating temperatures result in deterioration of flavor and increased thawing losses. Freezer storage temperatures of 0° to −10°F are satisfactory if properly controlled to give a uniform environment with a minimum of variation.

Distribution. Breakdown in the distribution system or in its efficiency can also result in serious problems with the quality of frozen meat. As is the case with storage temperatures, fluctuations in temperature during distribution also severely impair quality. The problems created are even more acute, since the distribution system is frequently in the hands of a retailer or distributor over which the processor has no control. Many attempts to market frozen meat have failed largely because of problems in distribution.

Color of Frozen Meat. The color of frozen meat can be a serious problem. Freezing accelerates metmyoglobin formation, causing an undesirable color change. This is particularly noticeable in storage under display lighting. Blind packages and storage in the dark minimize metmyoglobin formation in frozen meat. Rapidly frozen meat is lighter in color than slowly frozen, but the relative desirability of the different products has not yet been determined by consumer panels.

Precooked Frozen Meat Products. The production of precooked frozen meat products has increased rapidly in recent years. These products often are complete meals, such as TV dinners, of which meat is the major component. The same problems that apply to frozen meats also apply to the precooked frozen items.

Good raw products and proper cooking methods are necessary to obtain good precooked frozen products. Selection of the other foods that are often used with these products becomes more complicated, as every item must be of adequate quality. Since these products are cooked, rapid cooling is also necessary to prevent deterioration prior to freezing. Packaging is just as important as for fresh-frozen meat.

The addition of other foods to the complete meal may have its advantages, as one can use spices and sauces to aid in preventing oxidative rancidity. Many of the vegetables contain natural antioxidants and can protect precooked meats from oxidative rancidity during freezing and storage.

Precooking methods must also be carefully considered, to obtain the best products, since different methods of cooking have a major influence on flavor and acceptability. The meat is often partially cooked before adding the other ingredients.

The problems encountered in distribution of fresh-frozen meat are also associated with precooked frozen meats. Satisfactory results require close work with distributors and constant stressing of the importance of proper temperature control. Quality control is a problem that extends from the raw product to the dinner table, and the solution can come only through joint responsibility and effort.

Enzyme Treatment

Large quantities of meat are being tenderized by enzymes commercially, and in addition, tenderizers are also being purchased and used in the home. A new segment of the meat business has developed around enzyme tenderization. Enzyme tenderization of low-grade beef cuts has made beef competitive with chicken and fish. Increased numbers of fast food chains with low prices and a rapid turnover in volume has led to the development of profitable processing operations for producing enzyme tenderized steaks.

Theory of Enzymatic Treatment. Enzymes are capable of breaking down the connective tissues and contractile proteins, and thus increase tenderness. Although enzymes differ in their specific action, most of those used as tenderizers attack collagen, ground substance, and actomyosin. Some are also effective against elastin.

Most of the action, however, is on the surface of the meat. It has been shown that tenderization can be more easily and rapidly achieved by adding tenderizing agents to the water used in the rehydration of freeze-dried meat. Nevertheless, an appreciable amount of tenderization can be obtained by treating individual steaks with tenderizer. This is the way most meat is currently being tenderized.

Source of Enzymes. A variety of proteolytic enzymes are being utilized for tenderization of meat. They include not only animal and plant enzymes, but also those of fungal or bacterial origin. Of the animal enzymes, trypsin and chymotrypsin from the pancreas are both effective, but pepsin has little or no influence on tenderness. The plant enzymes most commonly used in meat tenderizers include papain from the papaya, ficin from the fig, and bromelin from the pineapple. Although bromelin is not effective in breaking down the sarcolemma—the membrane surrounding the muscle fiber—the plant enzymes are all quite active on the components of muscle and are widely used as tenderizers.

Bacterial proteases are available as tenderizers under various trade names and are effective meat tenderizers. They are largely derived from selected cultures of *Bacillus subtilis*. Other organisms that produce proteolytic enzymes can also be used for tenderization. *Aspergillus oryzae* and *Aspergillus flavus* are widely used for producing fungal proteases, which are also being used for enzymatic tenderization of meat.

Some researchers have suggested that different proteases be used to complement each other and act on specific components, whereas others will break down other meat components. However, mixtures are not always effective, as some enzymes interact and destroy each other's specific activity. Generally, most commercial operators of tenderizing operations find it advisable to buy enzyme preparations from reputable manufacturers, who can advise them on levels and methods of application.

Enzymatic tenderizers commonly contain other ingredients for seasoning or even to enhance tenderness. It is well known that sodium chloride alone will improve tenderness, so it is usually an ingredient of most tenderizers. Polyphosphates are also common ingredients of tenderizers, not only because of an effect on tenderness but because they reduce losses during processing and cooking. Tenderizers also commonly contain other enzymes as impurities, which may or may not improve the final product.

Method of Application. Tenderizers are most frequently applied as dips or sprays, although some are added in dry form. The meat is usually frozen afterward, which gives better control of the process in large-scale operations. Powdered dry tenderizers are available from grocery stores and are utilized most commonly in the home. Some may also be used by small restaurants.

Application should be according to the manufacturer's direction or the result of experimentation by the user. It should be remembered that too much tenderizer will make the meat mushy. The level of application depends on the strength of the preparation and method of application. Since different enzymes and combinations of enzymes behave differently, their properties must be considered in arriving at the best method of application. For example, papain demonstrates most of its tenderizing action during cooking, so uniform cooking of the treated product must be considered.

Antemortem Injection. Swift and Company Research Laboratories have patented antemortem injection of a proteolytic enzyme solution to obtain uniform distribution throughout the carcass (Goeser 1961). In this system, the vascular system distributes the enzyme solution throughout the tissues, the heart of the live animal serving as the pump. Beef produced by this procedure is sold under the trade name ProTen.

The enzyme utilized is fractionated papain and is active at cooking temperatures of 140°–160°F. It has been shown to cause significant improvement in tenderness. However, it has several disadvantages, one being the fact that each animal must be individually injected. Furthermore, the meat produced would not be suitable for use where it is kept at high temperatures for long periods, as occurs in institutional use or restaurants. Under these conditions, the high temperatures keep the enzymes active and thus cause tissue breakdown. Overtenderization of the soft tissues such as the brains, liver, and kidneys also seems likely.

Antemortem tenderization of meat is a most interesting application that illustrates how scientific principles can be applied to achieve a practical solution to meat tenderness. Significant improvement in tenderness can be obtained by this procedure. The process can be used by other processors through a licensing arrangement.

Other Possibilities for Enzymatic Tenderization. Although all the methods mentioned earlier involve use of added enzymes, it is well accepted that natural enzymes in meat play a role in development of tenderness during natural aging of meat. It should be possible to effectively activate these enzymes in meat and thereby achieve tenderization. Although a considerable amount of work has been done, results to date have not been promising.

Chemical Additives

Chemical additives have long been added to foods to preserve them or to enhance their physical properties. Salt is added not only as a seasoning but also as a curing agent. Phosphates are added to increase water binding. Ascorbates are added to stabilize color and to serve as antioxidants and more recently to prevent formation of nitrosamines during the curing and/or heating of processed meats containing nitrite. These are all examples of chemical additives that are commonly accepted by both the consumer and industry. Although new additives must be approved by the FDA, other additives are certain to play important roles in the preservation and processing of meat.

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18

Deterioration of Processed Meat

Manufacturers of processed meat products contend with two types of product deterioration: (1) flavor and (2) appearance. Each of these types of deterioration is referred to at both the processor and retail level as spoilage. Product spoilage can be obvious to the eye, as in the case of product greening, or obvious only to the nose or palate, as with rancidity. It is quite possible to have both types of deterioration present in processed meat products at the same time, but this is not always the case.

Deterioration of meat is a continuing phenomenon, beginning at the time of slaughter. The addition of curing agents, spices, and antioxidants, followed by thermal processing and smoking, slows down the deterioration process. All meat used in manufacturing processed meat products must be free of significant deteriorative flavor changes because it is impossible to reverse such changes. While the use of curing agents and thermal processing can greatly slow the onset of visible deterioration caused by microorganisms, flavor deterioration of meat prior to processing will carry through to the finished product. Seasonings, curing agents, and smoke tend to mask a limited amount of preprocessing deterioration, but significant raw material deterioration carries through and can usually be detected in processed meat products immediately after manufacture.

FLAVOR

Processed meat flavor deteriorates when rancid, putrefactive, or sour flavors develop.

Rancidity

Rancidity is caused by hydrolysis or oxidation. Bacteria can be the source of the enzymes: lipases cause hydrolysis and oxidases cause oxidation. Both give rise to the odors and flavors that are associated with rancidity.

Most rancidity problems encountered in meat products, however, are not of microbial origin but result from the reaction of oxygen with

A. M. Pearson et al., *Processed Meats*

unsaturated fats. Oxidation of fats is influenced by quantity of oxygen present, temperature, light, and pro-oxidant catalysts. Salt is the best example of such catalysts. In addition, various chemicals, such as ozone, hydrogen peroxide, and other strong oxidizing agents markedly influence the development of rancidity. One of the main reasons microorganisms are not a significant factor in the development of rancidity in meats is that the free fatty acids liberated by hydrolysis of fats inhibit the growth of many types of microorganisms. In addition, the peroxides formed during oxidation of unsaturated fatty acids are quite toxic to many microorganisms.

Warmed-Over Flavor. One of the more serious oxidative problems in cooked meats has been called "warmed-over flavor." The problem is not unique to cooked meats; it can occur in fresh meats where the membranes are disrupted during processing either by mechanical means or by cooking.

Warmed-over flavor can be prevented by the addition of nitrite or nitrate, thus, it is not usually a problem in cured meats. It is a serious flavor defect in most fresh restructured meats. It is first evidenced by a fading of the characteristic bright red color, followed by an apparent loss of flavor after cooking, and then by development of oxidized flavors.

Development of warmed-over flavor occurs rapidly after cooking and becomes very objectionable within a few hours after refrigerated storage. It is retarded by rapid freezing and freezer storage of cooked fresh meats, but is best prevented by use of antioxidants or preferably by using a sauce containing vegetables having natural antioxidants. Phosphates are also effective in preventing warmed-over flavor.

The phospholipids are the lipid fraction primarily responsible for warmed-over flavor. Disruption of the membranes releases these phospholipids as well as the oxidative catalyst, ferrous iron. The ferrous iron is released from the porphyrin ring of myoglobin and the highly unsaturated phospholipids of the membranes are exposed to oxygen. The net result is the rapid development of warmed-over flavor. Nitrite prevents the reaction by stabilizing the porphyrin ring and preventing release of ferrous iron.

Putrefaction

Certain proteolytic bacteria metabolize meat proteins through production of enzymes. Some cannot attack proteins but can metabolize peptides or free amino acids. Many of the degradation products resulting from bacterial metabolism of meat proteins have foul odors. The term putrefaction is generally used to describe this type of spoilage.

Souring and Gassing

Anaerobic metabolism of carbohydrates in meat products by bacteria results in various fermentation products, primarily organic acids. The principal acid formed is lactic acid; its presence brings about lowering of the meat pH and development of a sour flavor. Anaerobic bacteria can grow in the interior of large sausage products, and if a gas-producing variety is present, the gases evolved cause the sausage to become distended. This occurrence is rare, however. A much more common problem caused by anaerobic bacteria is the gassy vacuum package, in which gas-producing organisms on the surface of the sausage liberate a gas which in turn causes the package to become distended. The gas is carbon dioxide, which is colorless, odorless, and tasteless. Aerobic bacteria, yeasts, or molds are never implicated in this problem. The carbon dioxide results from a fermentation process induced by the anaerobic bacteria. Usually, but not always, when gas is produced, acid is also present, as the bacteria that cause gas formation usually form acid as well.

APPEARANCE

Spoilage associated with appearance of noncanned meat products is of three types: (1) microbial discoloration, (2) macroscopic microbial growth, and (3) nonmicrobial discoloration.

Microbial Discoloration

Microbial discoloration can be exhibited as green cores, green rings, surface greening, and color fading.

Green Cores. This condition is usually associated with large sausages such as bologna. It occurs when greening bacteria are introduced into sausage emulsions and are not destroyed during cooking. The bacteria survive in the interior of the sausages, but greening of the meat pigments does not occur until the sausages are cut and exposed to air. Greening bacteria, principally *Lactobacillus viridescens,* produce hydrogen peroxide, a strong oxidizing agent which degrades the meat pigment. Greening may occur within minutes, or it may be hours before the cut meat surfaces begin to turn green. Color changes begin in small areas, usually in the center of the meats, and extend from there to the periphery. Spreading of the green area is one of the characteristics which distinguishes microbiological greening from that caused by chemical or metallic sources. Cooking processed meat products to temperatures of 152°–155°F destroys greening organisms. However, on rare occasions, when the contaminating level is quite high, it is necessary to cook to an internal temperature of 160°F.

Green Rings. The appearance of green rings in sausages is a very rare occurrence. Although this problem has never adequately been explained, it appears that a combination of factors must be present.

Green rings appear at varying depths beneath the sausage surface. They usually develop within 1 to 2 days after the sausages are processed, and are noticeable as soon as the sausages are cut into, even though they have been held under adequate refrigeration. Although greening bacteria are present throughout the sausages, the discoloration develops in the form of rings probably because it is in this zone that the oxygen tension is conducive to pigment oxidation. At least this is the most frequently accepted theory for the occurrence of green rings. As with green cores, the condition is associated with the presence of large numbers of greening bacteria in the emulsion and subsequent undercooking of the sausages.

Surface Greening. One of the most common types of discoloration associated with sausages and smoked meats is surface greening. Unlike metallic or chemically induced greening, the amount of time required for development of greening caused by bacteria varies with the concentration of greening bacteria and conditions for their growth. Usually surface greening is not noticeable for at least 5 days after processing and often a couple of weeks. The bacteria that cause surface greening are the same as those which cause green rings and green cores. These bacteria are common contaminants of meat-processing operations. Therefore, given enough time and the proper environment for growth, many nonvacuum-packaged meat products will eventually show evidence of surface greening. Because these bacteria are aerobic, surface greening will not occur on products that have been vacuum-packaged.

Macroscopic Microbial Growth

Slime. When meat is heavily contaminated with bacteria or yeasts or both, a white or sometimes yellow slime will appear on the surface. This microbiological slime is not a metabolic substance produced by bacteria or yeasts but is, in fact, the bacteria themselves. Obviously, slime appears only when a product is contaminated with large numbers of cells. Seldom is slime noted on the surfaces of vacuum-packaged products, because there are fewer anaerobic than aerobic bacteria in nature and therefore they are less likely to contaminate meat products. Then, too, anaerobic bacteria usually produce enough acid to inhibit extensive aerobic growth. However, after a period of time, even in vacuum packages, the contaminating organisms multiply to the extent that they can be seen with the naked eye. Ordinarily, the free liquid associated with vacuum-packaged products is clear or straw-colored. When product contamination becomes severe, this liquid becomes milky in appearance. On nonvacuum-packaged products slime appears in the form of characteristic beads, sticky to the touch, and having an off-odor sometimes described as yeast-like.

Molds. Molds are common contaminants of many processed meat products. Molds are air-borne contaminants, whereas bacteria and yeast contamination results primarily from direct surface contact. Molds require less moisture than either bacteria or yeasts to survive. However, like aerobic bacteria and yeasts, molds need oxygen. In addition, they need head space to allow for growth of their stalks. Therefore, molds do not grow on meat products that have been vacuum-packaged. They are commonly found on bulk-packed processed meat products, and in particular those requiring extended ripening periods, such as dry sausages and Country cured hams. Molds are largely destroyed by the heat employed during thermal processing, and if they are found on cooked products it is the result of post-processing contamination.

Some molds of the genus *Aspergillus* and *Penicillium* produce carcinogenic secondary metabolites known as aflatoxins. Semidry and dry sausages and Country-cured hams that are stored at high relative humidities and high temperatures are most likely to be contaminated. Since aflatoxins are extremely toxic, care should be taken to avoid conditions favoring excessive mold growth during storage. Although not all molds produce aflatoxins, products that have a heavy mold growth should be avoided as aflatoxins have been found to be present on many such meat items.

Nonmicrobial Discoloration

Among the benefits achieved in curing meats is the conversion of oxygen-sensitive fresh meat pigments to more stable cured meat pigments. Nevertheless, the main cause of nonmicrobial discoloration, usually observed as color fading, is oxygen. Factors affecting the rate and extent of nonmicrobial discoloration are (1) amount of pigment actually converted to nitrosomyoglobin, (2) quantity of oxygen available for reaction with pigments, (3) storage temperatures, and (4) intensity of lighting.

The greater the efficiency of the curing process, the more resistant cured meats are to color degradation. At least 70% of the meat pigment available for curing should be cured. If curing efficiencies fall much below this, meats are undercured. The interior color of undercured meat products may range from faded pink through gray to a light green.

Fading is an oxidative process accelerated by light and influenced by storage temperatures. Vacuum packaging has contributed greatly to lengthening the shelf-life of cured meat. The low levels of oxygen in vacuum packages result in protecting processed meats from rapid onset of microbial spoilage, rancidity, and color fading.

For maximum prevention of deterioration, both microbial and nonmicrobial, meat products should be stored as close to 28°F as possible. However, in practice, cured meats are generally stored between 38°

and 45°F. Light, especially display-case illumination, catalyzes the oxidation of cured meat pigments and can accelerate the fading rate. For this reason, it is best not to expose cured meats to strong lights.

CANNED MEAT SPOILAGE

Canned food products are spoiled when the contents have undergone deleterious changes. This may occur when cans are damaged, though damage to cans does not necessarily indicate spoilage of the contents. However, can damage makes spoilage of the contents possible.

The ends of normal cans with good vacuums are slightly concave or flat. Cans with distended ends caused by positive internal pressure from the formation of gas are referred to as swells, also known as puffers or blowers. The term soft swell refers to cans whose ends can be moved by thumb pressure but cannot be forced back to their normal position. Hard swells are those in which both ends of the cans are firmly and permanently bulged. Flippers are normal-appearing cans whose end flips out when the cans are struck a hard blow; when light pressure is applied, the end snaps back to its original position. Springers are cans that have one end distended but when the end is forced back into its normal position, the opposite end bulges out. Swelled cans pass progressively through the flipper and springer stages. In the beginning, enough gas is produced to relieve the vacuum in the cans. At first, the cans may be flippers. As more gas is formed, the cans become springers and then swellers. Eventually, the pressure can cause the can to burst.

It is not always possible to tell the condition of the contents by appearance of the cans. Cans with spoiled contents may appear quite normal and show no signs of distortion. The causes of product spoilage or can defects are (1) microbial, (2) chemical, and (3) physical.

Microbial

Microbial spoilage results from (1) spoilage prior to retorting, (2) undercooking, (3) inadequate cooling, and (4) contamination resulting from leakage through can seams.

Spoilage Prior to Retorting. Gross bacterial growth can take place during preparation. If filled cans are not retorted promptly and are allowed to remain at elevated temperatures, bacterial contaminants may produce sufficient gas to cause the cans to swell. When the cans are retorted, the bacteria are killed, but the gas remains. Microbiological culture of the can contents yields no viable organisms, that is, these cans are invariably sterile, but numerous organisms can be observed upon microscopic examination.

Undercooking. Canned meat products that have not been cooked thoroughly enough to destroy bacteria or stop their activity are subject to spoilage. These bacteria may produce gas, causing the cans to become swellers. In other cases, acid is formed. When bacteria grow without evolving gas, the affected cans appear normal. Spoilage can be detected only when the cans are opened. Unless cans have been grossly undercooked, spoilage is generally due to spore-forming organisms.

Inadequate Cooling. Thermal processing to the extent necessary to destroy all microbial life usually results in severe deterioration of product quality. For this reason, retort schedules employed for cooking meat products are not so demanding and allow some thermophilic bacteria to survive the retorting process. Control of these bacteria depends primarily on rapid cooling of cans and their contents and storage at temperatures which do not allow thermophilic growth. Flat-sour thermophiles multiply rapidly between 120° and 160°F. Failure to cool cans immediately after retorting to below 120°F can lead to flat-sour spoilage.

Seam Leakage. Leakage through can seams is responsible for more microbial product spoilage than any other factor. The principal source of bacteria entering through leaks in the can is the cooling water. Use of chlorine in the cooling water drastically cuts the incidence of spoiled cans due to seam leakage. The principal type of leaker spoilage is swelling. This indicates that the leaks somehow become sealed. However, not every case of leaker spoilage is a sweller. If leaks are so large that they permit gas to pass freely, the cans will not swell. Sometimes the bacteria that contaminate the contents are not gas producers, and the cans remain normal in appearance.

Chemical

Chemical spoilage results in formation of a swell known as a hydrogen swell. This type of spoilage is the result of evolution of hydrogen gas during internal corrosion of the cans. Chemical spoilage is associated primarily with the can and not the contents.

Internal corrosion occurs most frequently in cans with foods containing organic acids such as fruits or, in the case of meat products, those containing curing salts. Use of properly enameled cans minimizes the chances for reaction of product with the tin plate.

Physical

Physical spoilage does not refer to the spoilage of contents but essentially to the appearance of cans. Often cans are distorted, giving the appearance of swells. However, the causes of this swell are not of bacterial or chemical origin but are the result of the processing techniques. Physical spoilage may also refer to rusting and physical damaging of cans.

Faulty Retort Operation. When steam pressure is reduced too quickly at the end of the retort process, high pressures develop inside cans. This may result in severe straining and distortion, so that when the cans are cooled they have the appearance of swells. Cans distorted in this manner have no positive internal pressure and the ends can be forced back more or less to their normal position. These cans are subject to a high incidence of leaker spoilage.

Cans not properly exhausted during the retort process may undergo severe strain due to excessive internal pressure built up by expansion of entrapped gases. If the amount of gas present is slight, underexhausted cans may show evidence only of slight flipping. On the other hand, if the amount is great, the cans may be greatly distended.

Overfilling. Cans which are overfilled often become strained during retorting due to expansion of the contents. The absence of vacuum in an overfilled can results in flipping or, in more severe cases, springing of the ends.

Paneling. This condition is primarily associated with larger size cans in which there is a very high vacuum. In this case, the can bodies are forced inward by atmospheric pressure. Paneling can also be observed in pressure-cooled cans which have been exposed to extremely high air pressure or in cans composed of thin tin plate. In severe cases paneling can result in seam leakage, particularly if the seam is already of marginal quality.

Rust. Product spoilage does not usually accompany can rusting; however, there is always a danger that severe pitting may accompany rusting. Proper drying of cans after retorting followed by dry storage will prevent rusting. Cans should be allowed to retain sufficient heat after they have passed through the cooling bath to evaporate water remaining on them. An internal product temperature of 95°F is usually sufficient to ensure rapid can drying.

Damage. Physical damage of cans caused by rough handling is cause for concern to the meat canner from an aesthetic viewpoint. In addition, such cans could become leakers, because physical damage usually puts severe strain on can seams.

Spoilage Bacteria

Canned meats and meat products are classified as low-acid, which means they have a pH of 5 or higher. Below pH 4.5, *Clostridium botulinum,* the most heat-resistant of the food-poisoning microorganisms, is inhibited. Therefore, for foods with a pH below 4.5, pressure cooking is considered to be unnecessary. Canned cured meats such as ham, luncheon loaf, and bacon usually are subjected to a relatively low thermal process because the curing salts present in the meat, together with the heat treatment, exert an inhibitory affect on the growth of *Clostridium botulinum* and other putrefactive anaerobes. The principal microorganisms causing spoilage in shelf-stable canned meats can be classified into two groups: (1) aerobic sporeformers, and (2) anaerobic spore-formers.

Aerobic Spore-Formers. Aerobic spore-formers responsible for spoilage of canned meat products belong to the genus *Bacillus*. These bacteria are widely distributed in nature, originating in soil and water, and are frequently present in the raw materials used in canning. The optimum growth temperature for most members of this group lies between 82° and 104°F, but many are also thermophilic and can grow at 131°F. Some of these microorganisms are strict aerobes, but others are facultative anaerobes. Their growth in canned foods is not inhibited by vacuum and many of the thermophilic strains exhibit exceptional resistance to heat destruction. The principal form of spoilage caused by aerobic spore-formers is the flat-sour type. Flat-sour refers to bacteria which attack carbohydrates with production of acid but without gas formation. In meat products that develop flat-sour spoilage, there is no loss of can vacuum and the can ends remain flat or concave. However, there are some members of this group which can form gas and, in this case, the ends of the cans become distended.

Anaerobic Spore-Formers. Anaerobic spore-formers are derived principally from soil and are quite widely distributed in food materials. Some species are present in animal intestines and are frequent contaminants of meat. As a result, spore-forming anaerobes are often associated with spoilage of canned meat products. Spore-forming anaerobes of the genus *Clostridium* can be grouped into two categories: (1) thermophilic and (2) mesophilic.

Thermophilic Anaerobes. These organisms grow at temperatures well above 100°F. Since most shelf-stable canned meats are not stored at these high temperatures, members of this group are not responsible for appreciable losses. This is not true, however, for members of the mesophilic group.

Mesophilic Anaerobes. A prominent member of this group is the pathogenic organism, *Clostridium botulinum*. Destruction of clostridia spores is generally accepted as the minimum standard of processing for low-acid canned meat products. However, *botulinum* organisms are not as heat-resistant as some other spore-forming anaerobes. Mesophilic spore-forming anaerobes can be classed roughly into two groups based on the relative ability of various species to attack proteins and carbohydrates. Those which are of greatest significance to the canned meat industry are the proteolytic or putrefactive anaerobes. *Clostridium sporogenes* and related strains appear to be the principal putrefactive anaerobes associated with spoilage of canned meat products. Generally, spoilage caused by putrefactive anaerobes is of the gaseous type, and usually the contents are at least partially disintegrated, resulting in formation of the characteristic foul odors associated with putrefactive spoilage.

Pasteurized Canned Meat

Provided they are refrigerated properly, pasteurized canned meats have a shelf-life well in excess of one year. Pasteurized canned meats are cooked sufficiently to kill all vegetative bacteria, but depend on adequate refrigeration and the cure ingredients, salt and nitrite, to prevent germination and growth of spores. If pasteurized meats are not cooked adequately, the most common spoilage microorganisms that survive are *Streptococcus faecium* and some lactic acid bacteria. They can cause souring and product discoloration. Still other bacteria that may survive produce gas, digest gelatin added to bind meat juices, or partially digest the meat. If pasteurized meats are adequately cooked but not refrigerated properly, both aerobic and anaerobic spore-formers may germinate and grow. Many of these can produce gas and may cause extensive putrefaction.

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Index

D

E

F

T

V

W