Meat Processing and Meat Preservation

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1. Introduction

Humans are innately omnivorous. In primitive times, humans lived as hunters and gatherers wandering the land in search of game animals as well as various botanical and marine resources. Humans are the only animal that know how to use fire, having learned that cooking makes meat tastier and easier to preserve. Thus, humans have learned how to process meat in many different ways.

Heating, drying, salting and smoking have been used as methods of preserving meat since ancient times. Refrigeration and freezing began to be used recently. The above methods are based on the principle of preventing contamination by microorganisms. Therefore, it is essential to study the role of microorganisms in the processing and preservation of meat. Also, it is necessary to examine the relation of meat varieties and properties to the production of processed meats of superior quality. This paper will describe briefly the problem of microorganisms, the properties of meat and the methods of meat processing and meat preservation.

2. Composition of Meat

In general, meat may be said to be composed of water, fat, protein, mineral (ash), and a small proportion of carbohyrate. Table 4 presents data for these components in some meats.

2.1 Water and Fat

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. 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.

2.2 Meat Proteins

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.

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 oxidative enzymes, including cytochromes, flavin nucleotides, and various heme pigments.

Myoglobin is the predominant pigment in muscle. Myoglobin has a great affinity for oxygen. This can be shown by exposing a freshly cut surface of meat to air, which results in a rapid brightening in color as the myoglobin takes up oxygen. In regard to age, young animals have less myoglobin 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.

Myofibrillar Proteins: Myofibrillar proteins are also known as contractile proteins by virtue of the key role they play in muscle contraction. After death, these proteins function in the development of rigor mortis. The principle proteins in the myofibrillar faction include myosin, actin, and the combination form of actomyosin, which results from contraction of muscle, or in the case of meat, during the development of rigor mortis. In addition, the myofibrillar fraction includes tropomyosin, troponin, a-actinins and perhaps other minor regulatory proteins.

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. 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 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.

2.3 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.

2.4 Minerals or Ash

Ash content accurately reflects the mineral content but does not differentiate the minerals present. Aside from bone or minerals added as curing salts or for seasoning, the mineral content of muscle is relatively constant.

3. Microorganisms in Meat and Meat Products

Microorganisms play an important role in the quality of meat, before, during, and after processing, by initiating many undesirable biological changes in meat. In addition, the age of the animal, method of slaughter, chilling of the carcass, storage conditions of the meat, and sanitary conditions after slaughter materially influence the quality of the end product.

Obviously, the number of organisms in meat products will vary widely due to external contamination of the carcass. Sanitation throughout the entire slaughter operation and subsequent processing becomes very essential in minimizing contamination and extending the keeping quality of meat.

3.1 Facts You Should Know About Microbes

The role of microorganisms in meat begins with the slaughter of a healthy animal whose flesh is considered essentially sterile or free from living organisms. After slaughter, as the many meat cuts are removed from the carcass, so begins the life story of the many varieties of microorganisms that inevitably inhabit and can thrive in meat foods.

Many names such as *molds, microbes, germs,* and, occasionally, names seldom seen in print, are used in reference to these microorganisms. These microorganisms have existed either before or after chilling of the carcass, before or after curing and smoking, in the retail stores, or even in the refrigerator at home.

Prevalence: Microorganisms exist everywhere. To the meat processor, it means that they can be found in the air, in the water supply, in all raw materials of meat and spices, in cartons, on utensils, on the skin and clothing of your employees, and on all of the surfaces of your equipment and buildings. You must accept the fact that microorganisms exist.

Size: Microorganisms are *small,* extremely small. This by itself constitutes one of the most serious problems one has when dealing with such organisms.

Shape: Microbes exist in a wide variety of forms, shapes, and even colors. The molds are the largest and exhibit many artistic forms and vivid colors. The yeasts are primarily round in shape, occasionally resembling a derby hat and intermediate in size. Bacteria, the smallest of the microbes, occur in various shapes and are usually the most difficult to identify, at least in distinguishing one species from another.

Growth: Bacteria multiply by fission, by splitting into two or more parts, and this process is continued over and over again. Yeasts reproduce by budding. A portion of the cell swells up and then separates from the parent. Molds elongate, and as this process continues, the molds branch out much like the growth of a tree. Molds are also capable of producing large numbers of spores (seeds).

3.2 Requirements for Growth

Meat, like milk, is an excellent source of practically all the essential nutrients necessary to establish the growth of microorganisms. Added to this problem is the fact that a processing house provides an ideal environment for microorganisms, having the necessary air, moisture, and temperature conditions.

Nutrients: Proteins, carbohydrates, fat, water, inorganic compounds (salt, nitrite, etc.), and even vitamins are found in all meat products, and in various combinations these substances make up the favorite diet of most organisms.

pH (acidity-alkalinity): Normally, most organisms prefer a near neutral pH (6.8-7.2). However, the organisms peculiar to meats and meat products are able to grow within a very wide pH range (4.0-9.0), and there may be exceptions even to these values. Fresh meat will normally have pH values in the range of 5.3 to 6.0. Processed meats can have widely divergent pH values; for example, fermented sausages will be quite acid (pH 4.2-5.7).

Air: Science has divided microorganisms into the following categories depending on their oxygen requirements.

1. Aerobes require oxygen for growth, and there are many species of bacteria, yeasts, and molds that can reproduce in the presence of varying amounts of oxygen. Vacuum packaging was conceived primarily to inhibit the growth of these organisms.
2. *Anaerobes* do not require oxygen for growth. Actually, it can be very toxic to them. Most of the anaerobes important to meats are bacterial species, as the canned meats division can verify. Yeasts are of some importance also; however, molds do not grow without oxygen.
3. *Facultative anaerobes* are organisms that will grow either with or

without air. Certain bacteria can be found to be the source of trouble on the surface of a product, and yet these same bacteria can cause an entirely different problem in the interior of another product. For all practical purposes, the interiors of fresh meats, hams, sausages, etc. do not contain free oxygen and therefore will only favor the growth of anaerobes or facultative anaerobes. Some of the lactobacilli, pediococci, streptococci, and coliform bacilli, as well as some yeasts, possess the ability to adapt themselves to the presence or absence of oxygen.

Moisture: Moisture is an important requirement for growth, as organisms can only utilize their food by assimilation, and the nutrients must therefore be in solution. The relative humidity (moisture in the air) can also affect the development of organisms. In general, bacteria require more moisture than do yeasts and mold, and this explains, in part, why molds and yeasts are found on the surface of dry and semidry meat products. A dry surface coupled with a dry atmosphere is not very conducive to bacterial growth.

And compounds such as sugar, salts, and phosphates, when dissolved in water, will tie up moisture. The amounts of such substances used in meat formulas, curing pickles, etc., are proportional to the amount of moisture rendered unavailable. High concentrations of salt and sugar in a meat product will actually act as preservatives by binding up moisture.

Temperature: The temperature at which microorganisms will live or die is undoubtedly the most important factor that decides their fate. Each microorganism has an optimum temperature at which it best develops, and the bacteria that are important to meat can flourish over a wide range of temperatures. We are able to classify the microorganisms into three main groups relative to temperature.

1. *Psychrophiles*—Those that like the cold and grow well at temperatures below 20°C. Many species will thrive at refrigerator temperatures (3-7°C) and are all too common in the packing house.
2. *Mesophiles*—Those that prefer warmer temperatures (21-38°C). The majority of bacteria fall into this classification. Body temperature is ideal for their growth.
3. *Thermophiles*—Those that prefer it hot, in temperatures around 54-60°C or even higher. By controlling temperatures we can often eliminate a great many problems. Therefore, to know when a meat product becomes contaminated and to know what temperatures will control it, is the big job.

4. Principles of Meat Processing

Processed meat products are defined as those in which the properties of fresh meat have been modified by the use of one or more procedures, such as grinding or chopping, the addition of seasonings, alteration of color, or heat treatment. Typical processed meat products include items such as cured ham, bacon, corned beef, and an almost endless variety of sausages. Most of these products are subjected to a combination of several basic processing steps before reaching their final form. Although each processed product has its own specific characteristics and methods of preparation, they all can be classified as either *comminuted* or *noncomminuted* products.

Typical noncomminuted products include hams of all types, bacons, Canadian bacon, and corned beef. In the meat industry, many of these products are commonly referred to as *smoked meats*. Their distinguishing characteristic is that they are prepared from whole, intact cuts of meat. These products usually are cured, seasoned, heat processed, and smoked, and often they are molded or formed. Most comminute products may be classed as sausages. Sausages are comminuted, seasoned meat products that may also be cured, smoked, molded, and heat processed.

4.1 Curing

Meat curing is the application of salt, color fixing ingredients, and seasonings to meat in order to impart unique properties to the end product. Two main ingredients must be used in order to cure meat; *salt*, and *nitrite*. However, other substances are added to accelerate curing, stabilize color, modify flavor and texture, and reduce shrinkage during processing. Salt (sodium chloride) is included in all meat curing formulas. Its main function is as a flavoring agent and has some preservative action. Nitrite, either as a potassium or a sodium salt, is used to develop cured meat color. It imparts a bright reddish-pink color, which is desirable in a cured product. Sodium or potassium nitrates were the first compounds used for this purpose. Nitrate and nitrite were often used in combination. Nitrates are now being removed from use in meat curing since nitrite will accomplish the desired reaction more rapidly. Nitrite must be reduced to nitric oxide before proper color development occurs and reductants are used to speed this reaction. The basic reaction occurring during color development is represented by the following equation.

$$\text{myoglobin} + \text{nitric oxide} \longrightarrow \text{nitric oxide myoglobin} \xrightarrow{\text{heat}} \text{nitrosyl hemochrome}$$

Nitric oxide myoglobin has an attractive, bright red color, and is the pigment present in the cured product prior to heat processing. The color is stabilized by the denaturation of the protein portion of myoglobin, for example, by heating. The resulting pigment is nitrosyl hemochrome which is responsible for the bright pink color characteristic of cured meat.

4.2 Comminution, Blending and Emulsification

The process by which particle size is reduced for incorporation of meat into sausage type products is called *comminution*. Some items are very coarsely comminuted, but other products are so finely divided that they form a meat emulsion. Two main advantages are gained from all comminution processes. These are an improved uniformity of product due to a more uniform particle size and distribution of ingredients and an increase in tenderness as the meat is subdivided into smaller particles.

Equipment commonly used for comminution includes the meat grinder, silent cutter, emulsion mills, and flaking machines. Grinders are usually employed for the first step in the comminution of sausage type products. For nonemulsified sausages, grinding is often the only form of comminution employed. In the past, the silent cutter was used to form meat emulsions, but it is now usually used to reduce the particle size of meat and fat, and for mixing ingredients, prior to their emulsification in an emulsion mill. Compared to the silent cutter, emulsion mills operate at much higher speeds, form emulsions in much less time, and produce emulsions that have a smaller fat particle size. Since emulsion mills operate at high speed, the meat materials are subjected to considerable friction. This results in a higher emulsion temperature in a mill than in a silent cutter. Excessively high temperatures can reduce the stability of the resulting emulsion.

Blending refers to an additional mixing to which comminuted products are subjected prior to further processing. The purpose of a separate blending step is to insure a more uniform distribution of ingredients, especially of the cure and seasoning, than could be achieved with just grinding. Coarsely ground sausages are blended prior to being stuffed into casings. Large batch blending of meat, seasonings, and other ingredients is a common procedure prior to emulsification.

4.3 Heating and Smoking

The smoking and heating (cooking) of processed meats can be considered as two separate processing steps. Most products are both smoked and cooked (frankfurters, bologna, and many hams). However, a few products are only smoked with a minimum of heating (mettwurst, some Polish sausages, and bacon) while others are cooked but not smoked (liver sausage).

Heating: Typical heat processed meat products are cooked until internal temperatures of 65-75°C are reached. This is sufficient to kill most of the microorganisms present, including the trichinae that are occasionally found in pork. The product is thereby pasteurized, and its shelf life significantly extended. Pasteurization is one important function of heat processing.

In addition to pasteurization, other important changes result from heat processing. Of special significance is the firm, set structure that develops as a result of protein denaturation, coagulation, and partial dehydration. For example, an emulsified product stuffed into a cellulose casing has no definite shape. The hardening and firming that occurs during cooking sets the structure so that when the casing is removed, the product's shape and form is retained. Similar changes occurring in smoked meat products, such as hams, give the product a more rigid structure, so that their shapes are retained during further handling, packaging, and distribution. A third important purpose of heat processing is to fix the cured meat pigment by the denaturation of nitric oxide myoglobin, previously discussed.

Some products, such as bacon, are heated only to an internal temperature of 52°C, at which temperature color fixation occurs (by the formation of nitorosyl hemochrome). Such products are not considered as being cooked meat products and, except for dry or semidry sausages and smoked meats, require further cooking before they are eaten. Meat inspection regulations require that products labeled as cooked (ready to eat hams, luncheon meat, frankfurters, and many others) must be heated to an internal temperature of 65-68°C.

Smoking: The smoking of meat is the process of exposing a product to wood smoke at some point during its manufacture. Smoking methods originated simply as a result of meat being dried over wood fires. The development of specific flavors, and the improvement of appearance are the main reasons for smoking meat today, even though smoking provides a preservative effect.

4.4 Aging

This process involves keeping the manufactured product for varying periods under controlled temperature and humidity conditions. There are several purposes for aging processed meat, including: (1) flavor development, (2) textural change, (3) completion of the various curing reactions, and (4) the drying and hardening of the product. The development of a distinctive flavor often results from microbial fermentation in the product. The organisms responsible for fermentation are usually lactic acid producing bacteria that can enter the product from the plant environment and processing equipment. Examples of such starter culture organisms are *Lactobacillus plantarum* and *Pediococcus cerevisiae.*

5. Methods of Meat Preservation

5.1 Heating

Heating (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.

Destruction of Bacteria and Improving Stability: Heating performs a most important function by causing destruction of spoilage organisms. The number of organisms destroyed will depend on spoilage organisms. The number of organisms destroyed will depend on the time and temperature relationship. (Table 5. 6. 7)

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. Heating also plays a major role in extending the shelf-life of such products. Sausages and smoked meats are normally quite stable under refrigeration (0-3°C), 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.

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.

5.2 Chilling and Freezing

Chilling: The chilling of carcasses consists of a rapid lowering of their temperature below 10°C and keeping them near 0°C. This method inhibits the growth of the anaerobic, mesophilic bacteria responsible for internal putrefaction and bone-taint and the pathogens causing food-borne diseases. The growth of aerobes on the surfaces, including many psychrophiles, is slowed down but not halted, which explains why meat cannot be stored chilled for long periods, unless it is vacuum packed. The major species present in the microflora of carcasses after slaughter are *Pseudomonas*, *Moraxella*, *Acinetobacter*, *Lactobacillus*, *Brochothrix thermosphacta* and a few Enterobacteriaceae, as well as various kinds of *Flavobacterium*, *Alcaligenes*, *Vibrio*, *Aeromonas*, *Arthrobacter*, yeasts and molds.

Good keeping quality of meats is ensured by rapid chilling to temperatures near 0°C. At such temperatures, the growth of pathogens and toxin production is inhibited.

For various species, bacterial growth is inhibited at the following temperatures:

5.2°C: inhibition of *Salmonella* growth;
10.0°C: inhibition of *Staph. aureus* toxin production;
6.7°C: inhibition of *Staph. aureus* growth;
6.5°C: inhibition of *Cl. perfringens* growth, which is already

	slowed down at 20°C;
10.0°C:	inhibition of *Cl. botulinum* toxin production (types A and B);
3.3°C:	inhibition of *Cl. botulinum* toxin production (type E).

Obviously, none of these pathogenic species that can be found in meat are able to grow below 3.3°C.

A rapid lowering of the carcass temperature after slaughter will produce shortening phenomena, probably caused by disruption of the sarcoplasmic reticulum by low temperatures. As a result, rigor mortis will cause sarcomere contraction and increase the toughness of meat after cooking. The effects of cold-shortening assume greater importance when the muscles are separated from the bones during hot boning.

Freezing: Freezing has long been recognized as an excellent method for the preservation of meat. It results in less undesirable changes in the qualitative and organoleptic properties of meat than the other methods of preservation. In addition, most of the nutritive value of meat is retained during freezing, and through the period of frozen storage. The only loss in nutritive value occurs when some of the water soluble nutrients are lost in the drip during thawing. The amount of drip varies with the freezing and thawing conditions, so the nutrient losses from frozen meat vary correspondingly.

The length of time that meat is held in refrigerated storage prior to freezing also effects the ultimate qualitative properties of frozen meat. In addition, the quality of frozen meat is influenced by the freezing rate, length of freezer storage, and freezer storage conditions. These later conditions include such important factors as the temperature, humidity, and the packaging material that is used. Included among the changes that can occur during frozen storage are the development of rancidity and discoloration. At temperatures below about—10°C, most deterioration due to microbial and enzymatic activity is essentially curtailed.

During cryogenic fast freezing the temperature of the meat product being frozen rapidly falls below the initial freezing point. Numerous small ice crystals tend to form uniformly throughout all of the meat tissues. These small ice crystals have a filament-like appearance, and they are formed with approximately the same speed, both intra- and extracellularly. Because of the rapid temperature drop due to the rapid rate of heat transfer, the numerous small ice crystals that form have little opportunity to grow in size. Thus, fast freezing causes the spontaneous formation of many individual small ice crystals resulting in a discontinuous freezing boundary and very little translocation of water. Since most of the water inside the muscle fibers freezes intracellularly, drip losses during thawing are considerably lower than in the thawing of slow frozen meat.

The thawing process probably does greater damage to meat than freezing. First of all, thawing occurs more slowly than freezing, even when the temperature differential is the same. However, the temperature differential in thawing is generally much less in practice than that encountered in freezing. Secondly, during thawing the temperature rises rapidly to the freezing point, but then remains there throughout the entire course of thawing. This situation further increases the length of the thawing process, compared to freezing. The thawing process thus provides a greater opportunity for the formation of new, large ice crystals (recrystallization), for increased microbial growth, and for chemical change. Thus, the time-temperature pattern of thawing is more detrimental to meat quality than that of freezing.

5.3 Drying

Hot air drying is a slow process that is not applicable to large pieces of cooked meat (such as roasts, steaks, or chops) because the resultant surface hardening yields a product with poor consumer acceptability. Meat products dried by hot air also shrivel considerably, and have poor rehydration properties due to the protein denaturation that occurs during the drying operation. However, such factors as temperature, particle size, and the rate of air movement must be carefully controlled. Meat products dehydrated in this manner have a residual moisture content of about 5 percent. As a consequence, certain deteriorative changes can develop during prolonged storage. The fat, especially that of pork, tends to become rancid following hot air drying. This can be retarded either by the addition of antioxidants, or packaging the product in a manner that eliminates oxygen.

In conventional freeze drying, the meat product remains frozen throughout the drying cycle while its internal frozen water (ice) is removed by the application of sufficient heat to transform it directly to water vapor without going through the liquid state. The freeze drying process is carried out in a vacuum chamber, and if vacuum pressures of 1.0-1.5 mm of mercury are used, the drying chamber temperature can be as high as 43°C without causing any thawing. The rate of freeze drying is limited by the rate that heat can be transferred into the meat product in order to continue the process of sublimation.

Freeze dried meat products retain essentially their original shape and size. Consequently they are very porous, and are much more readily rehydrated than hot air dried meat products. However, the texture and flavor of freeze dried raw and precooked meat is greatly affected by the method of rehydration.

5.4 Chemicals as Meat Ingredients

A number of ingredients that are added to meat products during processing, including the application of smoke, impart varying degrees of preservative properties. The preservative action of sodium chloride in curing meat has long been known, and probably has the longest history of usefulness. Preservation by salt is achieved by its effectiveness in lowering water activity. However, lowering the water activity to a level necessary for effective preservation requires a salt content in the finished product of approximately 9-11 percent. This is considerably higher than the 2-3 percent commonly found in commercially cured meat products. While some microorganisms are inhibited by these latter salt concentrations, the water activity is usually high enough to support the growth of molds, yeasts, and halophilic (salt loving) bacteria. Thus, the salt in commercial processed meat products today only provides a limited preservative effect, and other methods of preservation are necessary in order to prolong their shelf life.

The addition of nitrite to processed meat products provides them with marked bacteriostatic properties. Nitrite effectively inhibits the growth of a number of bacteria including pathogens, most notable among which is *Clostridium botulinum*. The nitrite in cured canned meat products, that are thermally processed, aids in destroying the spores of anaerobic bacteria and inhibits germination of the surviving spores. In fact, the addition of 150-200 ppm of nitrite to canned or vacuum packaged processed meat products prevents the formation of botulinum toxin that may occur at lower nitrite levels.

Table 1 Meat production in the world (Unit: 1,000 t)

Country	Year 1969-71	1980	1984	1985	1986
France	4,079	5,360	5,562	5,491	5,558
West Germany	3,823	5,239	5,269	5,259	5,473
United Kingdom	2,654	3,071	3,213	3,260	3,184
USSR	12,438	14,981	16,969	17,131	17,726
USA	21,339	24,626	25,551	26,085	26,529
Argentina	3,210	3,721	3,376	3,579	3,623
Indonesia	315	444	669	718	761
Japan	1,634	3,028	3,259	3,476	3,513
Korea	166	556	728	800	817
Philippines	509	736	843	813	821
Thailand	422	651	853	901	939
China	14,056	22,753	18,418	20,881	22,637

Table 2 Domestic meat production and imported meats in Japan

(Unit: 1,000 t, *1989)

	beef	horse	pork	chicken	sheep
Domestic meat production	548	4	1,593	1,114	0.2
Imported meats	452	36	345	270	69

Table 3 Domestic meat products and imported meat products in Japan

(Unit: 1,000 t, *1989)

	ham	pressed ham	bacon	sausage
Domestic meat products	170	13	71	280
Imported meat products	19	—	0.9	4.5

Table 4 Typical chemical composition of meat

	Percent
Water (range 55-75)	70
Protein (range 16-22)	18.5
myofibrillar	(9.5)
sarcoplasmic	(6.0)
stroma	(3.0)
Non-Protein Nitrogenous Substances	1.5
Fat (range 3-27)	8.0
Carbohydrates	1.0
Inorganic Constituents	1.0

Table 5 Conditions for the growth and the thermal death time of pathogenic bacteria

Species	thermal death time (min, 4D)*		memorandum
Vibrio marinus	25 °C,	80	Psychrotroph, Water born bacteria
Serratia spp.	30 °C,	30	Water born bacteria
Pseudomonas fragi	50 °C,	7.4 (D) **	Psychrotroph
Ps. fluoresens	53 °C,	4 (D)	Water born bacteria
Flavobacterium ferrugineum	52 °C,	10	Water born bacteria
Brevibacterium ammoniagenes	55 °C,	10	Short rod
Yersinia enterocolitica	62.8 °C,	0.7-17.8 (D)	
Serratia marcescens	60 °C,	0.17 (D)	Red color
Escherichila coli	60 °C,	0.3-3.6 (D)	
Salmonella typhimurium	55 °C,	10 (D)	
Klebsiella pneumonia	47 °C,	60	Coli form group
Propionibacterium acnes	60 °C,	0.18 (D)	
Acetobacter aceti	60 °C,	10	
Staphylococcus aureus	60 °C,	0.43-2.5 (D)	Yellow color
Streptococcus faecalis	60 °C,	0.83-13 (D)	Enterococcus
Strept. lactis	60 °C,	0.11-0.35	Lactic acid bacteria
Lactobacillus bulgaricus	71 °C,	30	Thermophilic lactic acid bacteria
Pediococcus cerevisiae	60 °C,	8	Halophobic lactic acid bacteria
B. subutilis (cell)	50 °C,	1.93 (D)	Sporeforming bacteria

* The time required for 99.99 % extinction
** The time required for 90 % extinction

Table 6 Heat tolerance of non-sporeforming bacteria

Species	thermal death time (min, 4D)*		memorandum
Vibrio marinus	25 °C,	80	Psychrotroph, Water born bacteria
Serratia spp.	30 °C,	30	Water born bacteria
Pseudomonas fragi	50 °C,	7.4 (D) **	Psychrotroph
Ps. fluoresens	53 °C,	4 (D)	Water born bacteria
Flavobacterium ferrugineum	52 °C,	10	Water born bacteria
Brevibacterium ammoniagenes	55 °C,	10	Short rod
Yersinia enterocolitica	62.8 °C,	0.7-17.8 (D)	
Serratia marcescens	60 °C,	0.17 (D)	Red color
Escherichila coli	60 °C,	0.3-3.6 (D)	
Salmonella typhimurium	55 °C,	10 (D)	
Klebsiella pneumonia	47 °C,	60	Coli form group
Propionibacterium acnes	60 °C,	0.18 (D)	
Acetobacter aceti	60 °C,	10	
Staphylococcus aureus	60 °C,	0.43-2.5 (D)	Yellow color
Streptococcus faecalis	60 °C,	0.83-13 (D)	Enterococcus
Strept. lactis	60 °C,	0.11-0.35	Lactic acid bacteria
Lactobacillus bulgaricus	71 °C,	30	Thermophilic lactic acid bacteria
Pediococcus cerevisiae	60 °C,	8	Halophobic lactic acid bacteria
B. subutilis (cell)	50 °C,	1.93 (D)	Sporeforming bacteria

* The time required for 99.99 % extinction
** The time required for 90 % extinction

Table 7 Heat tolerance of bacterial spores

Species of bacterial spore	thermal death time (min, 4D)*	
Bacillus (aerobic rod)	100 °C,	2 - 1,200 (D) **
B. megaterium	100 °C,	1 - 2.1
	121 °C,	0.02 - 0.04
B. cereus	100 °C,	0.8 - 14.2
	121 °C,	0.0065
B. subtilis	100 °C,	11.3
	121 °C,	0.08 - 5.1
B. coagulans	121 °C,	0.4 - 3
	100 °C,	30 - 270 (D)
B. sterothermophilus	100 °C,	714
	121 °C,	0.1 - 14
Clostridium (anaerobic rod)	100 °C,	5 - 800 (D)
C. butyricum	85 °C,	18
C. sporogenes	90 °C,	34.2
	121°C,	0.15

* The time required for 99.99 % extinction
** The time required for 90 % extinction

Discussion

Dr. A. A. Bakar (Malaysia): Besides NO_2 are there any other substances that can be used to impart a pink attractive colour to cured meat products?

Answer: At this point there are none. NO_2 is used for three reasons: 1) to impart a good colour, 2) to improve the flavour, and 3) to prevent the bacterium botulinus from developing.

Dr. Aguilar (Philippines): What would you suggest as a possible method of preserving meat in rural areas in tropical countries, using the indigenous materials available?

Answer: Curing with salt, pepper and other spices, and then drying.