MEAT PRODUCTS

1. Introduction

The new dietary guidelines for Americans and the new food guide pyramid issued by the U.S. Department of Agriculture (USDA) and the Department of Health and Human Services (DHHS) recommend a diet low in fat, saturated fat, and cholesterol. Following the guidelines does not mean omitting animal products from diets. Meat is not only a flavorful product, but it also provides protein and essential minerals and vitamins, especially B vitamins (1). Meat consumption varies with social, economic, political, and geographical differences on a worldwide basis. Income is an important factor affecting demand for meat (2).

This article discusses several aspects of processed meat products including meat processing ingredients, procedures, and machinery; hazard analysis critical control point; fat reduction in meat products; sous-vide processing; economics; nutritional labeling; and health and safety concerns.

2. Meat Processing Ingredients

2.1. Meat. The primary ingredient in processed meats is meat itself. The contents of myofibrillar, sacroplasmic, and stromal proteins within the meat products determine the characteristics of the finished meat product. The ability of various meat ingredients to provide extractable protein for functionality in binding water and fat as well as in the cohesion of meat particles varies tremendously. The structure and composition of muscle varies greatly with the anatomy of individual animal as well as with the species. Certain aspects of the anatomy that are high in collagen provide ingredients that are of little value from the standpoint of protein functionality. If this meat is to be used in processing of comminuted meat products, it is often necessary to combine it with meats that have a lower content of stromal protein.

The sacroplasmic proteins myoglobin and hemoglobin are responsible for much of the color in meat. Species vary tremendously in the amount of sacroplasmic proteins within skeletal muscle with cattle, sheep, pigs, and poultry listed in declining order of sarcoplasmic protein content. Fat is also an important component of meat products. The amount of fat in a portion of meat varies depending on the species, anatomy, and state of nutrition of the animal. The properties of processed meat products are greatly dependent on the properties of the fat included. Certain species, such as sheep, have a relatively higher proportion of saturated fat, whereas other species, such as poultry, have a relatively lower proportion of saturated fat. It is well known that the characteristic flavors of meat from different species are in part determined by their fat composition.

2.2. Salt. Salt is a common nonmeat ingredient added to meat products. Meat products may vary in salt content from 1–8%. In addition to enhancing the solubilization of the myofibrillar protein, salt gives flavor and has a preservative effect by retarding bacterial growth. The amount of salt used depends on the finished product characteristics desired by the meat processor. The vast majority of cooked sausage products contain approximately 2–3% salt. Myofibrillar proteins, which significantly affect meat product texture, are soluble only in salt solutions.

The effect of ionic strength on meat protein solubilization plays a significant role in the production of sectioned and formed, minced, and finely comminuted meat products.

2.3. Water. Water is often added to processed meat products for a variety of reasons. It is an important carrier of various ionic components that are added to processed meat products. The retention of water during further processing of meat is necessary to obtain a product that is juicy and has higher yields. The amount of water added during the preparation of processed meat products depends on the final properties desired. Water may be added to a meat product as a salt brine or as ice during the comminution step of sausage preparation.

2.4. Phosphate. Sodium tripolyphosphate [7758-29-4], sodium pyrophosphate [7722-88-5], disodium phosphate [7558-79-4], and sodium acid pyrophosphate [7758-16-9] alone or in combination are used at varying levels in meat products. Generally, the use of phosphate is restricted to an amount that results in not more than 0.5% in the finished meat product. When used in combination with salt, alkaline phosphates enhance the ability of myofibrillar protein to bind water during heat processing (3). It is thought that the mechanism of action of the alkaline phosphates is to break the bond between myosin and actin within the myofibril. In addition, the alkaline phosphates affect meat hydration by increasing the pH and ionic strength. By raising the pH of meat there is an increase in negative charges on the myofibrillar proteins. The negative charges on adjacent myofilaments repel each other, thereby allowing more space for water to be entrapped within the gel structure.

2.5. Nitrite. Sodium nitrite [7632-00-0] is added to cured meat products to fix their color and flavor, to inhibit *Clostridium botulinum* growth and toxin formation (4), and to stabilize lipids against oxidation (5). When nitrite is added to meat for the purpose of curing, less than 50% of that added can be analyzed after the completion of processing (6). The processor may add up to 200 ppm of sodium nitrite.

The level of sodium nitrate is not to exceed 500 ppm in the finished product (7). Many cured meat items contain only a few parts per million when they are consumed. The nitrite has either been lost from the meat to the atmosphere or remains in the meat as a reaction product undetectable by current analytical methods. When nitrite is added to meat products it reacts with the myoglobin and hemoglobin of trapped red blood cells to stabilize meat color to the cured form. Initially, the color changes from the purple-red of myoglobin to the brown of metmyoglobin. Eventually the color is converted to the rather dark red of nitric oxide myoglobin. When heated, this compound is converted to the pigment of nitrosylhemochrome, which is pink.

To assure safe use of nitrite, labeling must include name of additive, concentration, and in the case of retail packaging, the label must bear a statement to keep out of reach of children.

2.6. Extenders. Extenders are used in the processing of some meat products. The desirable functional properties of extenders are that they must be good binders of water, good binders of fat, commercially sterile, free from objectionable flavors and taste, appropriately colored, and readily available at competitive prices. Extenders are available from both plant and animal sources. Wheat gluten is a good water binder and holds two to three times its own weight of water. If used beyond the 3% level, it tends to give a rubbery texture to sausage. Rusk, a bread-type product which is recrumbled, is an extremely good water absorber prior to cooking, but tends to exude some of this water after the product is held for some time. Soy flour (50% protein), soy protein concentrate (70% protein), and soy protein isolate (90% protein) are usually used as a powder in finely chopped meat products. Sodium caseinate [9005-46-3], a water-soluble form of the dried milk protein, is a good fat binder and its protein level usually exceeds 90%. Blood plasma is also used in some parts of the world in the processing of meat products. Blood plasma must be prepared and included in meat products under highly sanitary conditions (8).

2.7. Seasonings. Seasonings which include spices, herbs, aromatic vegetables, flavor enhancers, and simulated meat flavors, may influence flavor, appearance, or shelf-life of meat products. The most commonly used spices in meat products are peppers (ground black, white, or red), nutmeg, mace, ginger, cardamom, celery, cumin, dill, and mustard. An example of a flavor enhancer is monosodium glutamate [142-47-2]. It brings out and intensifies the species flavor of the meat product. Hydrolyzed vegetable proteins have more flavor of their own which can be described as a meaty or beefy (8).

2.8. Curing Accelerators. The main function of curing accelerators is to accelerate color fixing or to preserve color of cured meat products during storage. Curing accelerator agents permitted in meat processing include ascorbic acid [50-81-7], erythorbic acid [89-65-6], fumaric acid [110-17-8], glucono delta lactone [46-80-2], sodium acid pyrophosphate, sodium ascorbate [134-03-2], sodium erythorbate [7378-23-8], citric acid [77-92-9], and sodium citrate [68-04-2]. Each of these agents has different legal limits of use in different cured products. In addition, curing accelerators must be used only in combination with curing agents.

2.9. Starter Cultures. A starter culture is required for the production of fermented sausage and it must possess a unique set of physiological characteristics. A starter culture must (*1*) be tolerant of salt, (*2*) grow in the presence of at least 100-μg nitrite per gram of meat, (*3*) grow in the range of 26.7−43.3°C (80−110°F) and preferably with an optimum around 32.2°C (90°F), (*4*) be homofermentative, (*5*) not be proteolytic or lypolitic, (*6*) not produce off-flavor, and (*7*) be safe and possess no health risk involved upon its application. Several microorganisms used as starter cultures for fermented meat products include *Lactobacillus plantarum*, *Lactobacillus sake*, *Lactobacillus acidophilus*, *Aeromonas* X, *Aeromonas 19*, *Micrococcus aurantiacus M-53*, and *Pediococcus cerevisiae* (9).

3. Meat Processing Procedures and Machinery

3.1. Mechanical Tenderization. Sophisticated advances have been made in improving meat tenderness. Mechanical tenderization involves the application of blades, knives, pins, or needles to meat via mechanical pressure. The increase in tenderness associated with mechanical tenderization is attributed to the partial destruction of connective tissue or the severance of muscle fibers, which leads to reduced resistance to shear force and mastication. Meat from various species is mechanically tenderized by being passed through a reciprocating blade-type machine. Sanitation is extremely important. The mechanical tenderizer tends to distribute the microorganisms that are on the surface throughout the interior of the meat pieces (10).

3.2. Cured Meats. The term meat curing means the addition of salt, nitrite and/or nitrate, sugar, and other ingredients for the purpose of preserving and flavoring meat (11). Cured meat products include ham, bacon, frankfurters, bologna, and some sausages. The slowest rate of meat curing is performed by applying the curing ingredients to intact meat pieces in the form of a dry rub. Such methods of curing are still being used for some meat cuts in certain parts of the world. It takes a long time for the cure to penetrate into the internal portion of larger meat cuts. With the increased costs of materials and labor, the amount of meat that is cured in this manner is declining.

Immersion curing is used as an alternative to dry curing. Immersion curing is still commercially used by some small processors. The meat is placed in a brine solution for an appropriate period of time until the brine penetrates the entire portion of meat. It is important not to keep the brine for too long a period of time because the brine strength is thereby reduced and the brine becomes contaminated with meat juices and bacteria.

With injection curing the brine is pumped into the meat with a needle and a pressurized source of liquid. The brine can be injected either through the arterial system in some large cuts such as hams, or it can be stitch pumped into the meat cuts by using a needle that has holes along its length. Both artery and stitch pumping are performed by hand and are relatively slow procedures. Multineedle injectors are most widely used in the industry for brine injecting bone-in or for boneless pieces of meat. The injected meat cuts are subsequently subjected to a mechanical action such as tumbling or massaging. This mechanical action physically disrupts the muscle structure, allowing the brine to interact more effectively with the extractable, salt-soluble myofibrillar proteins and to maintain the extracted proteins in a solubilized state. When the product is heated or cooked, the solubilized proteins form a gel entrapping the liquid more effectively within the product. This effective entrapment of moisture leads to a higher yield and more tender and juicy finished products (8).

3.3. Sectioned and Formed Products. The meats that are utilized to produce sectioned and formed products may be entire muscles, very coarsely ground meat, or flaked meat. Large sections may be produced by cutting muscle chunks into sections by hand or using a dicer. Some particles can be produced by using a plate in a meat grinder that has large kidney-shaped holes. Meat particles can be produced by using a flaking machine that is capable of varying the flake size from very fine to coarsely flaked materials. The mechanical energy that must be applied to the various size of meat pieces and other ingredients to extract myofibrillar proteins can be provided by a mixer, tumbler, or massager. Tumbling generally refers to placing meat inside a stainless steel drum that rotates at such a speed that some of the meat is carried to the top of the drum and drops down at least one meter onto the meat at the bottom of the drum. This impact of meat on meat, as well as the friction of one portion abrading another, has several functions: (*1*) it aids in abrading the myofibrillar proteins from the meat surface, (*2*) it makes the meat more pliable, and (*3*) it increases the rate of cure distribution. Massaging is generally a less severe mechanical treatment than tumbling. Massagers come in many sizes and designs. Most models use a bin similar to a standard meat vat which is equipped with a large motor to power a vertical shaft that has arms attached to it. The massager slowly stirs the large chunks of meat to achieve the same results as the tumbler.

3.4. Minced Products. Many meat products are produced by grinding or mincing meat to various particle sizes. The products that are included in this class are sausages of the fresh, fermented, dried, and cooked varieties. The meat ingredients can be either ground in a mincer or chopped in a bowl chopper. If particle definition and size are to be maintained, the meats should be cold when either ground or chopped. In order to obtain uniform particle reduction it is necessary to keep the grinder blades and plates in excellent working condition and maintain very sharp knives in the bowl chopper. The presence of connective tissues must be carefully controlled if a high quality product is to result. If the product is to be cooked and the particle-to-particle binding is to be maintained during cooking, and the maximum amount of fat and water retained, it is necessary to mix the meat ingredients along with salt so as to extract myofibrillar proteins. The extracted myofibrillar proteins act to bind the particles together and to trap water and fat during cooking.

3.5. Finely Chopped Products. The manufacture of finely comminuted processed meat products is dependent on the formation of a functional protein matrix within the product. The ability of the protein to successfully entrap moisture and fat is affected by many factors. These factors include the water holding capacity of the meat as well as the levels of meat, water, fat, salt, and nonmeat additives in the formulation. A certain level of fat is important in sausage products since it affects tenderness, juiciness, and flavor. The machines used to reduce the meat particle size are selected based on the variety and volume of the operation. Minced sausage production basically ends after comminution by a grinder, bowl chopper, or flaker, whereas the production of finely chopped sausage requires additional particle size reduction with more time in a bowl chopper or passage through an emulsion mill. In the bowl chopper, comminution and mixing are accomplished by revolving the meat in a bowl past a series of knives mounted on a high speed rotating arbor which is in a fixed position so that the knives pass through the meat as the bowl turns. Emulsion mills operate on a principle of one or more rotating knives traveling at an extremely high speed so that the meat mixture is pulled from a chopper and forced through one or more perforated stationary plates. The meat is drawn through tiny pores in these plates, and the mill therefore has the function of reducing the meat and fat particles to a very small size (2.0 mm or less), producing a smooth batter with paste-like consistency. This type of consistency is often desired for the finely chopped sausages and loaves.

3.6. Fermented Products. Fermented meat products such as semidried and dried sausages are generally recognized as safe, if critical points during processing are controlled properly. Some of the sausage processors use a small amount of fermented product as the starter for a new batch of product. This can be a dangerous procedure due to the potential growth of food poisoning bacteria such as *Staphylococcus aureus* (12). This method of inoculation requires a very strict condition to assure the absence of not only bacteria associated with a health hazard but also those associated with product failure (proteolytic, greening, and gas-forming microorganisms).

The use of a straight nitrate cure in sausages such as the Lebanon type requires mixed starters including *Micrococcus aurantiacus M-53* and *Lactobacillus plantarum*. The *Micrococcus aurantiacus M-53* ensures color formation by reducing the nitrate to nitrite, while the *Lactobacillus plantarum* is responsible for the decrease in pH (13). The fermentation in sausage involves the conversion of either sucrose or glucose to lactic acid by homofermentative lactic acid bacteria. This biological acidulation can reduce the pH value of the meat mixture from approximately 6.0 to 4.8 or 5.0. Attempts to slowly add lactic acid directly to the meat mixture were not successful, because the fermentation conditions cannot be substituted by direct chemical acidulation (9).

3.7. Sous-Vide Processing. The term sous-vide (pronounced *sue-veed*) means "under vacuum." In sous-vide processing, meats are cooked slowly in sealed, vacuumed, heat-stable pouches or thermoformed trays, so that the natural flavor, aroma, appearance, moisture, and nutrients are retained within the product (18). Such a method is not new, because early civilization used many ingenious ways of cooking foods in a wrapping (eg, leaves) to retain natural flavor and to maximize juiciness. However, what is new about the sous-vide process is the highly controlled packaging/cooking conditions used. Technically, sous-vide is a modified atmosphere packaging (MAP) or controlled atmosphere packaging (CAP) method. What makes it different from the ordinary MAP/CAP methods is the post-packaging pasteurization step. Sous-vide processing is used extensively in Europe and is gaining in popularity as a food processing method in North America.

Sous-vide processing consists of the preparation of top-quality raw ingredients, precooking (if necessary), packaging in heat-stable air-impermeable bags under vacuum to remove all of the air, sealing, and cooking (pasteurization) at a particular temperature for a certain period of time. The pasteurized product is cooled to 4°C within two to three hours of pasteurization, and stored and distributed under refrigerated conditions (19). A MAP/CAP product gradually deteriorates over time beginning with the day it was packaged. For sous-vide products, under good manufacturing conditions, a shelf life of 21 to 30 days is obtainable. The sous-vide product also facilitates the preparation of tasty meals on reheating for 10–15 minutes in boiling water or four to five minutes in a microwave oven (19). However, a significant concern about these minimally processed products is that they are not shelf stable. Therefore, they could be a potential public health risk if subjected to temperature abuse at any stage of production! storage, distribution, and marketing.

4. Hazard Analysis Critical Control Point

The hazard analysis critical control point (HACCP) concept is a systematic approach to the identification, assessment, prevention, and control of hazards. The system offers a rational approach to the control of microbiological, chemical, environmental, and physical hazards in foods, avoids the many weaknesses inherent in the inspectional quality control approach, and circumvents the shortcomings of reliance on microbiological testing (14,15). The food industry and government regulatory agencies are placing greater emphasis on the HACCP system to provide greater assurance of food safety. In the 1970s and early 1980s, the HACCP approach was adopted by large food companies and began to receive attention from segments of the food industry other than manufacturing. Reports by the International Commission on Microbiological Specifications for Foods (ICMSF) revealed a growing international awareness of the HACCP concept and its usefulness in dealing with food safety (16).

4.1. HACCP Principles. The National Advisory committee on Microbiological Criteria for Foods established seven principles for the HACCP system (17).

Conduct Hazard Analysis and Risk Assessment. A hazard is any biological, chemical, or physical property that may cause an unacceptable consumer health risk. All of the potential hazards in the food chain are analyzed, from growing and harvesting or slaughtering to manufacturing, distribution, retailing, and consumption of the product.

Determine Critical Control Points. A critical control point (CCP) is any point in the process where loss of control may result in an unacceptable health risk. A CCP is established for each identified hazard. The emergence of foodborne pathogens has taught food processors the importance of potential product contamination from the processing environment.

Establish Specifications for Each CCP. It is necessary to include tolerances at each CCP. Examples of specifications or limits include product pH range, the maximum allowable level of bacterial counts, and the time and temperature range for cooking.

Monitor Each CCP. It is necessary to establish a regular schedule for monitoring of each CCP. The schedule could be, for example, once per shift, hourly, or even continuous. Preferably, a published testing procedure for the monitored parameter should be available.

Establish Corrective Action. Corrective actions should be clearly defined beforehand, with the responsibility for action assigned to an individual.

Establish a Recordkeeping System. It has always been important for the food manufacturer to maintain records of ingredients, processes, and product controls so that an effective trace and recall system is available when necessary.

Establish Verification Procedures. Verification can be performed independently by the manufacturer and the regulatory agency to determine that the HACCP system within the plant is in compliance with the HACCP plan as designed.

4.2. Example of an HACCP System. The HACCP system can be used to ensure production of a safe cooked, sliced turkey breast with gravy, which has been vacuum packaged in a flexible plastic pouch and subjected to a final heat treatment prior to distribution (20). Raw turkey breasts are trimmed, then injected with a solution containing sodium chloride and sodium phosphate. Next, the meat is placed into a tumbler. After tumbling, the meat is stuffed into a casing, placed onto racks, and moved into a cook tank, where it is cooked to an internal temperature of at least 71.1°C (160°F). After cooking, the meat is chilled. Next, it is sliced and placed into a pouch. Rehydrated gravy is then added, and the pouch is vacuum sealed. The product is then pasteurized. Finally, it is chilled, placed into cartons, and moved to storage for subsequent distribution. This process has six CCPs (ie, cooking, chilling, rehydrating, pasteurization, chilling, and storing–distributing–displaying). The process control objectives are to destroy the normal spoilage microflora and pathogens, and to control the potential for toxin produced by *Clostridium botulinum*.

Each CCP can be divided into three components: conditions, monitoring, and verification. Cooking, for example, could include the following. (*1*) *Conditions*: the internal temperature of 71.1°C (160°F) provides a substantial margin of safety for destroying nonspore-forming pathogenic bacteria. The product is relatively large in diameter and requires a long period of time for heating and chilling at temperatures that are lethal to vegetative cells. To assure compliance, it is necessary to have uniform product thickness and heat distribution within the cook tank. (*2*) *Monitoring*: a sensor is used to monitor the temperature of the water. The minimum internal temperature of the product is monitored by a temperature sensor placed at the center of a turkey roll. The temperature can be continuously measured and recorded. Water circulation or agitation to assure uniform heating can be monitored visually. (*3*) *Verification*: temperature sensors should be periodically calibrated for accuracy. Heat distribution should be tested using multiple temperature sensors placed throughout the cook tank. The frequency of verification depends on experience with the equipment and product, and the potential risk presented to consumers.

5. Fat Reduction in Meat Products

Consumers not only prefer good tasting foods, but they also are concerned with the nutrition, safety, and wholesomeness of the products they consume. The amount of fat, especially saturated fat and cholesterol in meat products, is of concern to a growing number of health-conscious consumers. The introduction of low fat ground beef sandwiches and hamburgers in fast food chains as well as closer trimming of retail beef cuts and leaner ground beef in supermarkets across the United States demonstrates the meat industry's response to consumer desires for lower fat consumption (21). In order to be labeled as low fat, a meat product must contain no more than 10% fat (22). The palatability of ground beef, however, is directly related to the fat content. The overall acceptability of ground beef products is maximized at a fat content of approximately 20% (22). As the fat content of ground beef decreases, there is a significant decrease in product juiciness and tenderness (24).

5.1. Leaner Cuts. The most obvious method for decreasing fat content in further processed red meat products is to use more trimmed, boneless cuts or leaner raw materials. A notable example has been the production of restructured or sectioned and formed hams or beef top rounds with less than 5% fat content (more than 95% fat free) in which visible surface and seam fat have been removed. Restructured steaks and chops offer processors greater opportunity to control fat content, portion size, and raw material costs but have different sensory characteristics as the fat content increases. Typically, muscles or trimmings from the chuck, round, or pork shoulder can be defatted, decreased in particle size, blended with ingredients, and shaped into the desired form. As a whole, flavor and overall palatability of restructured steaks and chops are not dramatically different over the 10 to 20% fat range (25). Further reductions in fat below 10% in restructured meats and sausages can be formulated by using less caloric dense ingredients such as fat reduced beef or pork, partially defatted chopped beef or pork, and mechanically separated meat or poultry.

5.2. Ingredient Additions and Substitutions. Processed meat products have the greatest opportunity for fat reduction for modification because their composition can be altered by reformulation with a fat replacement.

Added Water. Frankfurters and bologna are allowed to contain combinations of fat and added water not to exceed 40% with a maximum fat content of 30%. This allows, for example, a 10% fat frankfurter to be produced with 30% added water. Substitution of large amounts of fat with water alone may not give the optimal sensory and textural properties that consumers want (26). To overcome these shortcomings, several binders can be added to improve water and fat-binding properties, cooking yields, texture, and flavor (8).

Protein-Based Substitutes. Several plant and animal-based proteins have been used in processed meat products to increase yields, reduce reformulation costs, enhance specific functional properties, and decrease fat content. Examples of these protein additives are wheat flour, wheat gluten, soy flour, soy protein concentrate, soy protein isolate, textured soy protein, cottonseed flour, oat flour, corn germ meal, nonfat dry milk, caseinates, whey proteins, surimi, blood plasma, and egg proteins. Most of these protein ingredients can be included in cooked sausages with a maximum level allowed up to 3.5% of the formulation, except soy protein isolate and caseinates are restricted to 2% (27).

Carbohydrate-Based Substitutes. Most of the carbohydrates available for use as fat substitutes in processed meats fall into the category of being a gum (hydrocolloid), starch, or cellulose-based derivative. Carrageenan [9000-07-1] is possibly the most widely used binder in current low fat meat products. There are three types of carrageenan: iota-, kappa-, and lambda-carrageenans. Iota- and kappa-carrageenans act as gelling agents. The lambda type is nongelling, and functions as a thickner. Iota-carrageenan has been recommended (28) for use in formulating low fat ground beef due to its ability to retain moisture, especially through a freeze–thaw cycle which is typical for ground beef patties. Oat bran and oat fiber can also be used to improve moisture retention and mouth feel. Modified starches can be used as binders to maintain juiciness and tenderness in low fat meat products. Maltodextrins (dextrose equivalent less than 20) may be used as binders up to 3.5% in finished meat products. Other carbohydrates such as konjac flour, alginate, microcrystalline cellulose, methylcellulose, and carboxymethylcellulose have also been used in low fat meat products.

Functional Blends. The term functional blend refers to various ingredient blends formulated to achieve a certain objective such as fat reduction. An example of this blend consists of water, partially hydrogenated canola oil, hydrolyzed beef plasma, tapioca flour, sodium alginate, and salt. This blend is designed to replace animal fat and is typically used at less than 25% of the finished product. Another functional blend is composed of modified food starch, rice flour, salt, emulsifier, and flavor. A recommended formula is 90% meat (with 10% fat), 7% added water, and 3% seasoning blend (21).

Noncaloric Synthetic Fat Substitutes. For new synthetic fat substitutes to succeed in the preparation of low fat meat products, they must be technically superior to existing substitutes and offer greater versatility while mimicking the taste, texture, and function of fat, but without the calories. Although only few synthetic compounds (ie, polydextrose, sucrose polyester, esterified propoxylated glycerols, dialkyl dihexadecymalonate, and trialkoxytricarballate) are available, they may have greater market potential in the future, because they are microbiologically more stable and contribute less calories than the carbohydrate- or protein-based substitutes (27).

5.3. Other Technologies for Fat Reduction in Meat Products. *Surimi-Like Process.* Surimi is a wet, frozen concentrate of myofibrillar proteins from fish muscle that is usually prepared by freshwater washing of mechanically deboned fish muscle followed by the addition of ingredients to prevent protein denaturation during freezing. This process also has application in converting meat trimmings or mechanically separated meats into highly functional and nutritious ingredients (29). Production of beef surimi from mechanically separated meat removes up to 99.5% of fat and increases the protein content to 133–155% over the starting materials. The beef surimi is a bland-tasting raw material to which flavorings can be added (30).

Naturalean Process. This process claims to separate fat and cholesterol from conventionally deboned, trimmed lean by a process that finely minces the meat tissues in a high speed chopper, followed by the addition of a small amount of acetic acid to decrease the pH and aggregate proteins; then the fat is solidified on a cold surface heat exchanger (31). The lean component then can be removed from the surface of the fat and used for producing patties, sausages, emulsion products, meat fillings, or toppings.

Supercritical Fluid Extraction. Supercritical fluid (SCF) extraction is a process in which elevated pressure and temperature conditions are used to make a substance exceed a critical point. Once above this critical point, the gas (CO_2 is commonly used) exhibits unique solvating properties. The advantages of SCF extraction in foods are that there is no solvent residue in the extracted products, the process can be performed at low temperature, oxygen is excluded, and there is minimal protein degradation (32). One area in which SCF extraction of lipids from meats may be applied is in the production of low fat dried meat ingredients for further processed items. Its application in fresh meat is less successful because the fresh meat contains relatively high levels of moisture (33).

Fat-Reduced Meat Process. Partially defatted chopped beef (PDCB) is typically produced in a batch process, where the desinewed raw material is heated in tanks prior to fat/lean separation. But temperature gradient from vessel surface to center causes variations in product temperature and process time, which results in partially denatured products with reduced binding, flavor, and nutritional properties. In the fat-reduced meat (FRM) process heat exchange is continuous. Water temperature is tightly controlled to a maximum of 43.3°C. The average tempering time is 10 minutes. After tempering, a proprietary separation process is used to separate the lean portion from fat. The defatted material is then frozen into thin sheets at −6.7 °C or below within two minutes. The FRM can be used in hamburger patties, hot dogs, sausages, luncheon meats, and canned meat products (34).

Microwave Cooking Pads. A simple and effective method of reducing fat in meat products involves the use of microwavable heating pads. These pads, made from nonwoven, melt-blown polypropylene materials, absorb fat lost during the cooking process, minimizing its contact with food, and more fat is allowed to cook out (35).

Enzymatic Conversion of Cholesterol. A decrease of cholesterol in meat products in the future may be possible through the conversion of cholesterol [57-88-5] to coprosterol [360-68-9], which is not absorbed readily in the intestine. Cholesterol reductase can be isolated from alfalfa leaves and cucumber leaves (36). Treatment of meat animals might involve an injection of this enzyme immediately prior to slaughter, allowing for the conversion of a portion of the membrane-bound cholesterol into coprostanol.

6. Economic Aspects

Global meat markets are expected to recover gradually in the aftermath of animal disease outbreaks that have plagued the sector for the past years. Meat prices are expected to rebound. Meat shipments are expected to rise up 7% to 22×10^6 in 2007. Poultry prices are also rebounding, but have yet to recover fully. Pig meat was in abundant supply in 2006 so prices fell by 16% in mid-2006. High stocks in Japan have led to a decline in Japanese import prices. While higher feed prices may lift pig meat prices in 2007, continued strong supply growth from integrated U.S. industries and a competitive exchange rate are expected to mitigate an increase in international prices. The U.S. export share is expected to rise from 16% in 2003 to 25% in 2007.

Despite tight supplies of world beef (induced by foot-and-mouth outbreaks and bovine spongiform encephalopathy), trade bans on North American beef and Argentine export bans the trade-weighted average of beef prices through mid-2006 was down marginally from 2005. See Fig. 1 for prices of selected meat products. Table 1 gives data on world meat markets.

Even though the U.S/capita consumption of red meat fell from 124 lb/yr in the 1980s to 110 lb/yr in 2002(based on boneless, trimmed weight), the import share of red meat for the U.S., largely beef and veal, rose from 6.6% to 9.3% (38).

Table 2 gives data on the U.S. meat trade (39). Table 3 gives data on the average annual expenditure per person for meat products. Urban and rural data are compared (40).

7. Nutritional Labeling

Descriptive terms which convey information about the nutritional value or quality of a food product are useful to consumers when making product choices in the market place. This information, ie, label, is easily seen when displayed on the food container or package. Obviously, space availability on a product's label is very limited. Therefore, the development of concise and informative labeling terms is important for consumers, food processors, and government regulatory agencies. The USDA's Food Safety and Inspection Service (FSIS) regulates the labeling of meat and poultry products, while FDA has responsibility over all other food labeling. The FDA regulations implement the Nutrition Labeling and Education Act of 1990. FSIS relies on its general authority under the Federal Meat Inspection Act (21 USC 601 *et seq.*) and the Poultry Products Inspection Act (21 USC 451 *et seq.*) as the basis for its nutritional labeling proposal. The FSIS strives to ensure that these products are free from adulteration, properly identified, and correctly labeled before leaving a federally inspected establishment or entering the marketplace (41).

7.1. Nutritional Labeling Content. As part of its efforts to harmonize labeling requirements with the FDA proposal, the FSIS mandates that nutrition information include the same 15 declarations required by FDA as well as allowing certain optional disclosures. The mandatory disclosures include calories, calories from total fat, total fat to nearest one-half gram, saturated fat to nearest one-half gram, cholesterol in milligrams, total carbohydrates in grams excluding fiber, complex carbohydrates in grams, sugars in grams including sugar alcohols, dietary fiber in grams, protein in grams, sodium in milligrams, vitamin A as a percentage of reference daily intake (RDI), vitamin C as a percentage of RDI, calcium as a percentage of RDI, and iron as a percentage of RDI. If the particular product contains insignificant amounts of eight nutrients, the abbreviated format should include calories, total fat, total carbohydrates, protein, and sodium. The optional disclosures include calories from saturated fat and unsaturated fat, unsaturated fat to nearest 0.5 gram (this is mandatory if fatty acid and/or cholesterol claims are made), polyunsaturated and/or monounsaturated fat to the nearest 0.5 gram, declaration of sugar alcohols in grams, insoluble and soluble fiber, potassium in milligrams, and thiamin, riboflavin, niacin, and other vitamins or minerals (if a claim regarding these nutrients is made) (42).

7.2. Service Size. The label presentation should allow the consumers to understand the nutrition contents of individual meat products, compare nutrition contents across product categories, and choose among relevant food alternatives. The establishment of serving sizes has been the most controversial aspect of the nutritional labeling either for the consumers or manufacturers, because there are wide varieties of product sizes on the market, and it is almost impossible to standardize these sizes. In addition, there is also considerable confusion on the definitions of serving and portion (43). The term serving was defined by FDA as a reasonable quantity of food suited for or practicable of consumption as a part of a meal by an adult male engaged in light physical activity, or by an infant or child under age four when the article purports or is represented to be for consumption by an infant or child under age four (21 CFR 101.9 (b). In contrast, FDA defined the term portion as the amount of food customarily used only as an ingredient in the preparation of a meal component, ie, one-half tablespoon of cooking oil or one-fourth cup of tomato paste.

In order to resolve this problem, USDA's FSIS proposed three options for establishing standardized reference serving sizes: 1 ounce or 100 grams, a single and uniform reference standard serving size using food consumption data, and a reference standard serving size based on dietary recommendations (44). A 1 oz or 100-g serving size would provide the easiest method for conversion and allow consumers to compare between meat and poultry products easily. However, the consumers may not realize that the information has to be converted to be meaningful in terms of the amounts they eat, because 1 oz or 100 g may not be a commonly consumed amount of meat or poultry products. There was virtually no support for the second option in establishing a single uniform serving size based on food consumption data. The third option would provide nutrition information on the recommended portions of foods. However, it would not provide information on what is actually being consumed. Currently, FDA and USDA's FSIS continue to cooperate and the goal is to establish standards that could be used by food manufacturers to determine label serving sizes and whether a claim such as low sodium meets criteria for the claim (44).

7.3. Nutritional Labeling Descriptors. In order to avoid confusion, descriptive terms must be accompanied by definitions which adequately explain the terms. In the case of nutrition-related claims, analytical sampling offers a means of assuring the accuracy of the stated claims. The USDA's FSIS has proposed a list of descriptors relevant for meat and poultry products (Table 4).

8. Health and Safety Factors

8.1. Fat Intake. Consumers have been warned that a diet high in fat increases the probability of chronic health problems and diseases including coronary heart disease (CHD). It seems the message is getting through as indicated by increasing public awareness on the link between CHD and high fat intake (45). Unfortunately, consumers often equate animal fat with saturated fat. This is misleading because there is no fat that is 100% saturated. Fat always consists of different proportions of saturated and unsaturated fatty acids. Pork fat (lard) and beef fat (tallow) have about 40 and 43% saturated fatty acids, respectively. In fact, the levels of saturated fatty acids in animal fats are similar to the amounts of saturated fatty acids in many commercial hydrogenated vegetable fats used for shortenings and margarines (2). The misleading designation saturated fat has misinformed the general public; consequently, consumers may eat less meat in order to prevent CHD, cancer, and other illnesses linked to meat in the diet. More recent recommendations suggest that regular consumption of a moderate amount of lean meats is a healthful practice (46–48).

The American Dietetic Association, the American Heart Association, and the National Heart, Lung and Blood Institute recommend 142–198 g (5–7 oz) of lean, trimmed meat daily. It was also pointed out that trimmed meat, especially red meat, provides large amounts of essential nutrients such as iron, zinc, vitamin B_{12}, and balanced protein. The idea that the risk of CHD and cancer can be greatly reduced by avoiding a meat-centered diet have prompted some consumer groups to demand healthy meat products. In response, meat producers began to produce leaner beef with the use of growth hormones, and meat processors developed various types of low fat meat products (49).

8.2. Growth Promotants. Livestock can be exposed to many chemicals used to promote growth, improve feed utilization, or enhance meat acceptability. In the late 1960s, the greatest concern to the public was diethylstilbestrol [56-53-1] (DES), a synthetic estrogen used to promote weight gain in cattle.

This became a focus of attention when residues of DES were occasionally detected in beef livers. In the 1990s DES is known to be carcinogenic and associated with reproductive disorders in humans when administered in high doses, and its use to promote weight gains in livestock has been banned in the United States (50). Since the early 1980s, bovine somatotropin [66419-50-9] (BST) and porcine somatotropin [9061-23-8] (PST) have been extensively studied. Somatotropin [9002-72-6] is a growth hormone that occurs naturally in animals. The safety of beef for human consumption from cattle treated with BST was determined in 1984 by the Food and Drug Administration (FDA). Some of the findings were (*1*) the protein structure of synthetic BST and that produced by cattle is virtually the same, and (*2*) BST has no biological effects on humans and is degraded in the digestive process, as are meat proteins (51). However, not everyone accepts the FDA findings. Some groups or individuals have argued that more testing is needed. The use of BST has been approved in the dairy industry, but the use of PST in the pork industry has not been approved by FDA for commercial use in the United States. Beta-adrenergic agonists that are known to promote growth such as clenbuterol [37148-27-9], cimaterol [54239-37-1], and L-640,033 improve the growth rate and feed conversion of sheep and poultry. Effects on swine are varied; definitive data on cattle are not yet available (52). β-Estradiol [50-28-2] and zeranol [55331-29-8] are available compounds that occur naturally and are very effective repartitioning agents, enhancing rates of protein and lean tissue production whenever present at effective levels in cattle depositing fat (53). Trenbolone acetate [10161-34-9] is another example of growth promotant, but its precise mechanism of action is unknown (54).

8.3. Antibiotics. Antibiotics may be administered on a one-time basis, for several days, or for longer periods. During the production of meat, the shorter periods of administration are generally for the treatment of a diseased condition; longer use at subtherapeutic dosages is intended to prevent disease, thereby increasing animal productivity while in the feedlot. The industry generally believes that subtherapeutic levels of antibiotics in the feed are essential to prevent economic losses under current husbandry practices (55). However, the use of antibiotics in livestock production has caused serious public concern that the hazardous antibiotic residues in meat are contributing to health problems in humans. Some scientists and consumer groups support the notion that continuous feeding of penicillin, tetracycline [60-54-8], and other antibiotics to livestock for disease prevention may result in development of antibiotic-resistant strains of bacteria and subsequently contribute to human illness. The National Academy of Sciences reported that it has never found data directly implicating subtherapeutic use of antibiotics in feeds as a risk factor in human illness (56). However, the public health implications associated with use of such compounds warrant continuing evaluation and monitoring.

8.4. Pathogens. Meat and meat products have a wide variety of microorganisms which could cause product spoilage or illnesses in humans. Occurrence of the microbial contamination varies with the location and the types of processing conditions. Pathogenic and spoilage microorganisms can be transferred to the meat during post-slaughter processing, storage, and handling. During slaughtering, many pathogens that may be present in the intestinal contents of the animals can contaminate the carcass and subsequently the processing tables and other equipment (57). *Salmonella typhimurium* can be transferred from raw poultry skin to other surfaces (58). *Staphylococcus aureus* can be transferred by human contact with the meat during processing. *Staphylococcus aureus* is a microorganism that produces severe gastrointestinal food poisoning through production of several toxins. Other pathogenic bacteria such as *Clostridium botulinum*, *Listeria monocytogenes*, *Escherichia coli*, *Yersinia enterolitica*, and *Bacillus cerreus* have also been found in contaminated meat products. Sufficient application of heat during cooking, however, destroys pathogenic and meat spoilage microorganisms and produces meat products that are commercially stable at ambient or refrigeration temperature. In addition, the heat treatment must be sufficiently severe to not only destroy the contaminating bacteria but also certain bacterial spores or toxins (59).

8.5. Trichinosis. Trichinosis is caused by parasitic nematode *Trichinella spiralis* that localizes in the muscles of pigs. People become infected by eating undercooked meat, most commonly pork. When ingested, infected meat is digested releasing the larval trichina into the intestine where they rapidly mature into adults, mate, and produce a large number of offspring. The larval offspring leave the intestine, enter the blood stream, and invade the muscles where they migrate extensively before becoming encapsulated within a microscopic cyst. When only a few larvae are ingested, the infection is so light as to go unnoticed. Heavier infections produce symptoms associated with the parasite in the intestines and in the muscles. Diarrhea followed by fever, generalized swelling, muscle pain, and extreme fatigue are characteristic symptoms of trichinosis. The heaviest infections may be fatal, usually because the heart or brain is severely damaged (60). For many years, hotels, restaurants, institutional food suppliers, and consumers cooked pork to 82°C to ensure the destruction of *T. spiralis*. Other methods including freezing (−30 °C for at least 16 h), irradiation (19 to 750 krads), and curing (combined with up to 3.5% salt) have also been used for the destruction of *T. spiralis* (61).

8.6. Bovine Spongiform Encephalopathy (BSE). BSE belongs to the family of diseases known as transmissible spongiform ecephalopathies. The widely accepted theory in the scientific community is that the agent is an abnormal form of a normal cellular prion protein. The abnormal prion does not evoke any immune response or inflammatory reaction in the host animal. BSE is diagnosed after an animal's death. There are no tests for detecting the disease in live animals.

Since 1986 there have been more than 180,000 confirmed cases of BSE in cattle worldwide. Over 95% have occurred in the United Kingdom. In addition, cases have been documented in 22 European countries, Japan, Israel, the U.S., and Canada. Agricultural officials in the U. K. have taken a series of actions to ban BSE. These actions include making BSE a reportable disease, banning mammalian bone-and meat-meal in feed for all feed producing animals, prohibiting animals over 30 months old in the animal and human food chain, and destroying all animals showing signs of BSE.

In 1997, the FDA published a final rule to provide that animal protein derived from mammalian tissue is prohibited from ruminant feed. Although BSE was not identified in the United States at that time, the U.S. hoped to prevent the establishment of BSE through animal feed. 21 *CFR* 589.2000 prohibited animal proteins in ruminant feeds and established a system of controls. Following the discovery of a cow with BSE in Washington State in 2003, the FDA provided guidance on the use of materials from BSE-positive cattle. 21 *CFR* 589.2001 is a proposed rule that outlines requirements intended to apply to food or feed for all animal species. It provides that no animal food or feed shall be manufactured from, processed with, or otherwise, contain cattle materials prohibited in animal feed. It also provides new requirements for renderers that handle cattle material prohibited in animal feed (62).

8.7. Food Safety Innovations. Recent industry innovations improving the safety of the United States' meat supply range from new pathogen tests, high-tech equipment, and supply chain management systems to new surveillance networks (63).

Meat processors face special challenges that weaken incentives to invest in food safety improvements. Some restaurant chains and large retailers are encouraging these processors to overcome these challenges. A firm will invest in food safety innovations only if it expects to reap benefits, such as an increase in sales, improved brand equity, consumer loyalty, and price premiums for safer foods.

Unfortunately, meat producers had difficulties appropriating the benefits of food safety since it is a difficult concept to market. Consumers cannot usually determine whether a food was produced with the best or worst safety procedures. Processing terms do not want to advertise their safety records and disclose the poorer safety records of competitors and also not to make specific guarantees that could expose them to higher liability. Some meat producers also lack the technological expertise.

In the past decade, large restaurant chains and foreign buyers have demanded stringent requirements for pathogen control. These companies are referred to as channel captains who monitor food safety up and down the food supply chain. Through contacts with these channel captains, meat processors are better able to appropriate the benefits of their investments in new food safety technologies.

One such innovation is the the development and commercialization of Frigoscandia's beef steam pasteurization system that effectively reduces pathogens on surfaces of newly slaughtered beef.

Government policy targeted at increasing information on safe and unsafe producers may help spur innovation. For example, enhanced food safety labels would be a large benefit.

BIBLIOGRAPHY

"Meat and Meat Products" in *ECT* 1st ed., Vol. 8, pp. 825–839, by H. R. Kraybill, American Meat Institute Foundation; in *ECT* 2nd ed., Vol. 13, pp. 167–184, by W. J. Aunan and O. E. Kolari, American Meat Institute Foundation; "Meat Products" in *ECT* 3rd ed., Vol. 15, pp. 62–74, by G. R. Schmidt and R. F. Mawson, Colorado State University; in *ECT* 4th ed., Vol. 16, pp. 68–87, by G. R. Schmidt and S. Raharjo, Colorado State

University; in *ECT* (online), posting date: December 4, 2000, by G. R. Schmidt and S. Raharjo, Colorado State University.

CITED PUBLICATIONS

1. G. M. Briggs and B. S. Schweigert, in A. M. Pearson and T. R. Dutson, eds., *Advances in Meat Research: Meat and Health*, Vol. 6, Elsevier Applied Science, New York, 1990, pp. 2–20.
2. S. D. Shagam and L. Bailey, *Agricultural Outlook*, 12–15 (Apr. 1992).
3. R. Hamm, in J. M. deMan and P. Melnychyn, eds., *Symposium: Phosphates in Food Processing*, AVI Publishing Co., West Port, Conn., 1970, p. 65.
4. J. N. Sofos, F. F. Busta, and C. E. Allen, *Appl. Environ. Microbiol.* **3,7** 1103–1109 (1979).
5. M. P. Zubillaga and G. Maerker, *J. Am. Oil Chem. Soc.* **64**, 757–760 (1987).
6. J. H. Hotchkiss and R. G. Cassens, *Food Technol.* **41**(4), 127–136 (1987).
7. "Sodium Nitrite," 21*CFR*172, sec. 1.72.175, revised April 1, 2006.
8. G. R. Schmidt, in H. R. Cross and A. J. Overby, eds., *Meat Science, Milk Science and Technology*, Elsevier Science Publisher B. V., New York, 1988, pp. 83–114.
9. R. H. Deibel, *Proceedings of the Meat Industry Research Conference*, American Meat Institute, Arlington, Va., 1974, pp. 57–60.
10. K. J. Boyd, H. W. Ackerman, and R. F. Plimpton, *J. Food Sci.* **43**, 670–672, 676 (1978).
11. J. Bard and W. E. Townsend, in J. F. Price and B. S. Schweigert, eds., *The Science of Meat and Meat Products*, W. H. Freeman Co., San Francisco, 1973, pp. 452–483.
12. L. E. Barber and R. H. Deibel, *Appl. Microbiol.* **24**, 891–898 (1972).
13. F. P. Niinivaara, *Reciprocal Meat Conf. Proc.* **44**, 59–63 (1991).
14. F. L. Bryan, *Hazard Analysis Critical Control Point Evaluations*, World Health Organization, Geneva, Switzerland, 1992, p. 4.
15. W. H. Sperber, *Food Technol.* **45**(6), 116–118, 120 (1991).
16. B. Simonsen and co-workers, *Intl. J. Food Microbiol.* **4**, 227–247 (1987).
17. National Advisory Committee on Microbiological Criteria for Foods, (NACMCF) *Hazard Analysis and Critical Control Point System*, Food Safety and Inspection Service, USDA, Washington, D.C., 1989.
18. *Prepared Foods* **161**(8), 98–100 (1992).
19. J. P. Smith, H. S. Ramaswamy, and B. K. Simpson, *Trends Food Sci. Technol.* **1**, 111–118 (1990).
20. C. E. Adams, *Food Technol.* **45**(4), 148–151 (1991).
21. G. H. Taki, *Food Technol.* **45**(11), 70–74 (1991).
22. D. E. Pzczola, *Food Technol.* **45**(11), 60–66 (1991).
23. W. R. Egbert and co-workers, *Food Technol.* **45**(6), 64–73 (1991).
24. B. W. Berry and K. F. Leddy, *J. Food Sci.* **49**, 870–875 (1984).
25. C. A. Costello, M. P. Penfield, and M. J. Riemann, *J. Food Sci.* **50**, 685–688 (1985).
26. J. R. Claus, M. C. Hunt, and C. L. Kastner, *J. Muscle Foods* **1**, 1–21 (1989).
27. J. T. Keeton, *Reciprocal Meat Conf. Proc.* **44**, 79–90 (1991).
28. D. L. Huffman and co-workers, *Reciprocal Meat Conf. Proc.* **44**, 73–78 (1991).
29. CAST, *Food Fats and Health*, Task Force Report No. 118, Ames, Iowa, 1991.
30. P. Whitehead, *Prepared Foods* **161**(6), 102 (1992).
31. *Food Engineering* **60**(9), 91 (1988).
32. R. R. Chao and co-workers, *J. Food Sci.* **56**, 183–187 (1991).
33. A. D. Clarke, *Reciprocal Meat Conf. Proc.* **44**, 101–106 (1991).

34. *Food Engineering* **61**(2), 53–54 (1991).
35. C. A. Costello, W. C. Morris, and J. R. Barwick, *J. Food Sci.* **55**, 298–300 (1990).
36. U.S. Pat. 4,921,710 (May 1, 1990), D. C. Beitz, J. W. Young, and S. S. Dehal (to Iowa State University Research Foundation, Inc.).
37. *Meat Market Assessment and Meat Statistics*, FAO, United Nations, http://www.fao.org., December 2006.
38. *Amber Waves*, report of the USDA Economic Research Service, Feb. 2004.
39. *U.S. Meat and Trade Tables*, Economic Research Service USDA, http://www.usda.org., updated June 8, 2007.
40. *Food Spending in American Households, 2003-04/EIB-23*, Economic Research Service, USDA.
41. K. F. Leddy, *Reciprocal Meat Conf. Proc.* **41**, 21–24 (1988).
42. P. Olsson and D. Johnson, *Meat and Poultry* **38**(2), 24–36 (1992).
43. D. V. Porter and R. O. Earl, *Nutrition Labeling: Issues and Directions for the 1990s*, National Academy Press, Washington, D.C., 1990, pp. 203–216.
44. USDA Food Safety and Inspection Service, *Fed. Reg.* **56**(229), 60302–60364 (1991).
45. R. B. Shekelle and S. C. Liu, *J. Am. Med. Assoc.* **240**(8), 756–758 (1978).
46. American Dietetic Association, *J. Am. Diet. Assoc.* **86**, 1663 (1986),
47. R. M. Mullis and P. Pirie, *J. Am. Diet. Assoc.* **88**, 191–195 (1988).
48. G. F. Watts and co-workers, *Brit. Med. J.* **296**, 235–237 (1988).
49. D. Putler and E. Frazao, *Food Rev.* **14**(1), 16–20 (1991).
50. Council for Agricultural Science and Technology, (CAST) *Hormonally Active Substances in Foods: A Safety Evaluation*, Task Force Report No. 66, Ames, Iowa, 1977.
51. D. P. Blayney, R. F. Fallert, and S. D. Shagam, *Food Rev.* **14**(4), 6–9 (1991).
52. L. A. Muir, in L. A. Muir, *Designing Foods: Animal Product Options in the Marketplace*, National Academy Press, Washington, D.C., 1988, pp. 184–193.
53. F. M. Byers, H. R. Cross, and G. T. Schelling, in Ref. 12, 283–291.
54. R. E. Allen, in Ref. 52, pp. 142–162.
55. Committee on the Scientific Basis of the Nation's Meat and Poultry Inspection Program, *Meat and Poultry Inspection*, National Academy Press, Washington, D.C., 1985, pp. 44–47.
56. U.S. Assembly of Life Sciences, *The Effects on Human Health of Subtherapeutic Use of Antimicrobials in Animal Feeds*, National Academy of Sciences, Washington, D.C., 1980.
57. R. C. Benedict, *Reciprocal Meat Conf. Proc.* **41**, 1–6 (1988).
58. M. O. Carson, H. S. Lillard, and M. K. Hamdy, *J. Food Prot.* **50**, 327–329 (1987).
59. A. M. Pearson and J. I. Gray, in Ref. 1, pp. 517–542.
60. P. M. Schantz, *Food Technol.* **37**(3), 83–86 (1983).
61. A. W. Kotula, *Food Technol.* **37**(3), 91–94 (1983).
62. *Proposed rules, Federal Register*, **70**(193), 58750–58571 (Oct. 6, 2005).
63. E. Golan, T. Roberts, and M. Ollinger, "Savvy Buyers Spur Food Safety Innovations in Meat Processing," *Amber Waves*, http://www.ers.usda.gov./Amber Waves, April 2004.

Glenn R. Schmidt
S. Raharjo
Colorado State University

Updated by Staff

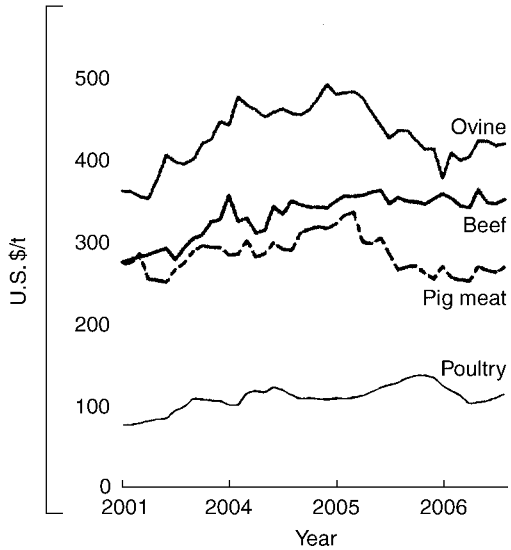

Fig. 1. Prices of selected meat products (37).

Table 1. **World Meat Markets, $\times 10^6$ t**[a]

World balance	2005	2006	2007	Change 2007/06 %
Production	**269.1**	**275.7**	**284.3**	**3.1**
bovine meat	64.5	65.7	67.5	2.8
poultry meat	82.2	83.1	85.5	3.0
pigmeat	104.0	108.0	112.0	3.7
ovine meat	13.1	13.5	13.8	2.7
Trade	**20.9**	**20.7**	**22.0**	**6.7**
bovine meat	6.6	6.6	7.2	9.2
poultry meat	8.4	8.2	8.7	6.4
pigmeat	4.8	4.8	5.0	4.2
ovine meat	0.8	0.8	0.9	4.6
Per capita food consumption world (kg/yr)	41.7	42.2	43.0	1.9

[a]Ref. 37.

Table 2. **Cumulative U.S. Meat Trade**[a]

	2005	2006	Jan.-Apr-07
Beef and veal imports		*Carcass wt, 1,000 lb*	
Australia	900,016	887,614	258,335
New Zealand	603,211	563,612	211,956
Canada	1,092,348	843,846	290,928
Brazil	214,355	273,209	94,577
Argentina	110,356	85,798	18,823
Central America	93,817	83,512	36,583
Uruguay	557,051	305,403	141,985
Mexico	26,720	40,760	15,993
other	635	878	1,462
Total	3,598,509	3,084,631	1,070,641
Beef and veal exports			
Japan	17,496	51,639	37,812
Canada	105,895	238,218	71,764
Mexico	464,024	668,369	183,217
South Korea	1,077	1,283	663
Caribbean	25,226	40,297	12,952
China (Taiwan)	22,394	67,364	20,369
other	61,046	85,234	46,606
Total	697,158	1,152,405	373,383
Lamb imports			
Australia	97,393	101,035	36,311
New Zealand	46,246	45,564	16,572
Total	144,240	147,130	53,067
Mutton imports			
Australia	33,782	41,067	17,155
New Zealand	2,066	2,170	1,173
Total	35,977	43,236	18,295
Lamb and mutton exports			
Mexico	5,953	12,386	2,715
Caribbean	1,441	2,709	874
Canada	1,295	2,157	420
Total	9,265	18,250	4,136
Pork imports			
Canada	836,728	793,159	258,839
Denmark	99,676	102,988	35,697
Poland	25,633	24,266	7,985
Netherlands	8,884	6,957	203
Hungary	2,788	1,987	529
other	50,140	60,316	21,433
Total	1,023,847	989,673	324,686
Pork exports			
Japan	1,045,956	1,014,521	373,884
Canada	302,211	324,786	103,922
Mexico	538,227	609,082	162,221
Russia	94,099	209,543	57,715
South Korea	190,085	293,449	119,545
Hong Kong	23,452	50,006	20,316
China (Mainland)	123,222	113,541	54,701

Table 2. (*Continued*)

	2005	2006	Jan.-Apr-07
China (Taiwan)	62,828	59,425	15,270
Caribbean	40,179	61,826	13,828
other	245,856	261,140	94,919
Total	2,666,116	2,997,319	1,016,322
Broiler exports		*Ready to cook, 1,000 lb*	
Japan	62,777	62,924	15,764
Mexico	522,454	457,647	138,837
Hong Kong/M.China	347,659	640,618	219,836
Singapore	94,452	98,050	35,215
Canada	229,537	237,904	81,462
Russia	1 681 338	1,599,019	454,269
CIS (excluding Russia)	384,994	329,550	141,556
Eastern Europe	218,804	123,431	2,290
Baltic countries	176,076	202 309	111,814
Caribbean	342 841	345,417	123,426
other	1,141,797	1,175,167	372,492
Total	5,202,730	5,272,034	1,696,961
Turkey exports			
Mexico	353,759	310,824	99,624
Canada	27,620	21,914	6,090
South Korea	4,913	6,867	1,673
Russia	20,009	25,240	6,748
Hong Kong	11,560	18,203	3,977
China (Taiwan)	19,770	17,990	3,098
other	131,919	145,205	45,564
Total	569,550	546,243	166,774

[a]Ref. 39.

Source: U.S. Dept. of Commerce.

Table 3. **U.S. Average Annual per Person Meat Expenditures ($) of all Households, 2004**

Item	All	Urban	Rural
Beef	107.05	105.60	116.92
ground beef (excluding canned)	39.05	37.51	49.53
chuck roast	4.75	4.55	6.12
round roast	4.14	4.06	4.65
other roast	9.45	9.52	8.97
round steak	6.67	6.52	7.68
sirloin steak	13.05	13.27	11.55
other steak	22.20	22.08	22.98
other beef (excluding canned)	7.74	8.08	5.44
Pork	73.08	70.72	89.13
bacon	12.56	11.77	17.94
pork chops	15.17	14.21	21.69
ham (excluding canned)	15.69	15.43	17.47
other pork	18.06	17.89	19.22
pork sausage	11.19	10.97	12.69
canned ham	0.40	0.44	0.13
Other meats	43.60	44.10	40.20
frankfurters	9.07	8.97	9.75
bologna, liverwurst, and salami	8.52	8.37	9.57
other lunch meats	20.91	21.39	17.64
lamb and miscellaneous meats	5.09	5.37	3.24
Poultry	62.89	65.00	48.56
chicken	49.51	51.19	38.06
fresh and frozen whole chicken	14.78	15.38	10.67
fresh and frozen chicken parts	34.73	35.81	27.39
other poultry	13.38	13.81	10.50

[a]Ref. 40.

Table 4. **Proposed Descriptors for Nutrition Labeling in Meat and Poultry Products**[a]

Descriptors	Criteria
	Ingredient-free
sodium-free	less than 5 mg of sodium per serving
salt-free	must meet the definition of sodium-free per serving
fat-free	less than 0.5 g of fat per serving, and no added fat or oil
percent fat-free	may be used only in describing foods that qualify as low fat
cholesterol-free	less than 2 mg of cholesterol per serving and has 2 g or less of saturated fat per serving
	Low content
low sodium	no more than 140 mg of sodium per serving and per 100 g of food
very low sodium	no more than 35 mg of sodium per serving and per 100 g of food
low calorie	no more than 40 calories per serving and per 100 g of food
low fat	no more than 3 g of fat per serving and per 100 g of food
low in saturated fat	no more than 1 g of saturated fat and no more than 15% of the food's calories come from saturated fat
low in cholesterol	no more than 20 mg of cholesterol per serving and per 100 g of food, and no more than 2 g of saturated fat per serving
	Reduced content
reduced calorie	one-third fewer calories than the comparison food
reduced sodium	no more than half of the sodium of a comparison food
reduced fat	no more than half the fat of a comparison food to avoid trivial claims, reduction must exceed 3 g of fat per serving
	Other designation
less	25% less of the nutrient than the comparison food
fewer	25% less calories than the comparison food
light or lite	one-third fewer calories than the industry norm and it may only be used when fat is reduced by at least 50%
lean	less than 10.5 g of fat, of which less than 3.5 g is saturated fat, and less than 94.5 mg of cholesterol per 100 g
extra lean	less than 4.9 g of fat, of which less than 1.8 g is saturated fat, and less than 100 mg of cholesterol per 100 g

[a]Ref. 44.