

CHAPTER 7

Meat and Meat Substitutes

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Chapter Objectives

THE STUDENT WILL BE EMPOWERED TO:

- Define the animal origins and cultural histories of various types of red meat.
- Describe properties of meat, such as its structural components, marbling, and pigmentation.
- Explain the changes that meats undergo during aging, preserving, and other processing methods.
- Define various cuts of meats.
- Compare and contrast commonly used dry heat and moist heat cooking methods.
- Explain the nutritional contribution of meat to the human diet.
- Discuss the impact that the meat industry has on the environment and ways in which this impact might be reduced.
- List steps that consumers of meat should take to prevent foodborne illness.
- Summarize the meat-inspection and meat-grading procedures followed in the United States.



FIGURE 7.1 Charolais cattle were developed in Charolais, France. They are a large-muscled breed, with bulls weighing as much as 1100 pounds.

Courtesy of the USDA, Farm Service Agency. Photo by Darcy Vial.

Gastronomy Point

Chinese Pork Archeologists have found recipes from more than 2000 years ago that demonstrate that the Chinese raised domesticated swine (pork) for human consumption.



FIGURE 7.2 Even though the breed was not introduced into the United States until the 1960s, today Charolais cattle are a common breed used by beef producers in the United States.

Courtesy of the USDA Agricultural Research Service. Photo by Keith Weller.

Historical, Cultural, and Ecological Significance

Livestock, including cattle, sheep, goats, and swine, serve multiple purposes in supporting the biological and ecological well-being of our planet. Among their many purposes, domesticated cattle, swine, and sheep play a large role in the food chain by providing food for human beings. Their muscle, organs, and fat are marketed to consumers as protein-rich, nutrient-dense meats, contributing significantly to the diets of those who consume them. Animals also provide humans with nutritional by-products such as milk and blood, which in some cultures are considered a central part of the diet. In addition, suppliers market other portions of the animals, such as their hides, wool, bones, and blood, to consumers. Leather—a durable material crafted from cowhide—is one example of an expensive animal by-product marketed to the clothing and furniture industries. Compared to the cost of raising plants, the cost of raising animals for food is extremely high; therefore, those who raise animals try hard to sell all parts of the animal so as to improve their profitability.

Animals have long served as food sources for human beings. In the Stone Age, humans consumed the meat of wild boar. However, because of the large size and difficult temperament of wild animals, the process of hunting and slaughtering them was very challenging. Domestication of animals made meat production much easier. Animals, beginning with sheep, were first domesticated for food around 9000 B.C. in the Fertile Crescent of the Middle East. Approximately 2000 years later, humans began domesticating other animals, including pigs (immature hogs) and cattle. These newly domesticated breeds were raised to be much smaller and more docile than their ancestors, and some even had alternative purposes. For example, domesticated cattle became popular for their strength and power shortly after the invention of the plow. The popularity of these domesticated animals quickly spread to other countries and continents.

Many of the animals domesticated for food purposes are not indigenous to North America. Cattle and sheep were brought to the Western Hemisphere by Columbus and the Spaniards in 1493. Hernando De Soto brought the first domesticated hogs to the New World in 1525. As these animals were bred and raised over the following centuries, large ranches and farms emerged in areas known today as Mexico, Texas, and Florida.

Beef

Beef primarily comes from the muscle tissue of full-grown steers and heifers brought to market at around 2 years of age. Steers are male cattle that have been castrated before sexual maturity; heifers are female cattle that have never reproduced. Beef can also come from the meat of cows (female cattle that have reproduced), bulls (noncastrated males), and stags (males that were castrated following sexual maturity); however, meat from cows, bulls, and stags is not typically as high in quality as meat from steers and heifers.

More than 100 million beef cattle roam the United States. Livestock producers categorize beef cattle as either British breeds or Continental European breeds. The British breeds, which include the Angus, Red Angus, and Hereford breeds, were introduced to the United States in the late 1700s, whereas the Continental European breeds, including the Charolais, Chianina, Gelbvieh, Limousin, and Simmental breeds, were not brought to the United States until the 1960s and 1970s (**Figure 7.1**).

More than 60 major breeds of cattle are raised in North America, but the most common breeds are Angus, Hereford, Charolais, Limousin, Simmental, Red Angus, and Gelbvieh (**Figure 7.2**). Beef cattle have varying degrees of fatness and palatability, and these traits are highly dependent on the

breed type. Regardless of the breed, though, most cattle weigh approximately 1000 pounds and can provide roughly half their weight in edible meat at the time of slaughter.

The raising of beef cattle starts with young calves that are milk fed immediately after birth. Calves are typically weaned onto either a grass- or grain-based diet at around 6 to 8 weeks of age. Beef cattle are typically grass fed, or pasture raised, immediately after weaning; dairy cattle usually transition straight to a grain-based diet. Beef cattle require large ranges and primarily consume forage until they are transported to a feedlot. In the feedlot, producers feed them a grain-based diet until the cattle's slaughter (**Figure 7.3**). The diet that is given to cattle and other meat-producing animals in the final months leading up to their slaughter is called the **finishing diet**.

A small percentage of beef cattle are allowed to roam free and consume forage until slaughter. Some people argue this form of feeding is more natural and humane and has a lighter environmental impact than feedlot finishing. However, due to limited space for grazing, most cattle farms in the United States cannot accommodate the large amount of land necessary for exclusively grass-fed cattle. In addition, the grain-based diet that is provided in the final 4 to 6 months of life helps to increase the cattle's overall body weight and, in turn, the farmer's profitability.

Most cattle are routinely injected with vaccines, antibiotics, and hormones soon after birth and prior to being brought to market. All cattle, including cattle that will be marketed as organic or natural and that do not receive any hormones or antibiotics, are vaccinated early in life to protect against liver abscesses and respiratory and clostridial diseases. These vaccines are estimated to cost \$3 to \$10 per cow-calf unit, and are an integral part of any herd health management plan (i.e., the systematic process by which cattle producers ensure viable, profitable beef production).¹

In addition to vaccines, most cattle receive antibiotics rich in ionophores—fat-soluble molecules that decrease bloating and reduce the risk of acidosis. Bloating and acidosis are two feeding problems commonly seen in cattle, and these problems can significantly decrease both feed efficiency and weight gain in beef cattle. Hormones, including those implanted in the animals, are also commonly administered to cattle to promote the absorption and metabolism of nutrients and to enhance weight gain. A study from Australia found that implantation of **hormonal growth promotants (HGP)** resulted in slaughter weights 4% to 7% greater than the slaughter weights of cattle that did not receive HGPs.² While steroid implant hormones are approved for use in beef and lamb, they are not approved for use in dairy cows (i.e., cows used to produce dairy products such as milk), veal calves, pigs, and poultry, including chicken and turkey.

Beef is a major staple in many Americans' diets, and over the past several decades, beef consumption has remained steady at approximately 57.4 pounds per person annually in the United States. However, Americans are not the only people consuming American meat. Beef is also a large export for the United States, with Canada, Australia, New Zealand, and Mexico all being countries that import large amounts of fresh and frozen beef from the United States. South American countries, including Brazil, Argentina, and Uruguay, also import large amounts of processed or canned beef from the United States.

Veal

Veal is the meat that originates from a young calf raised to age 16 to 18 weeks. Most veal found on the market is produced from male calves because, unlike females, male cattle do not produce milk and cannot be used as dairy cows.



FIGURE 7.3 Meat producers can minimize preslaughter fasting stress in cattle by feeding the animals regularly. This practice helps to maintain the normal balance of rumen microbes and suppress bacteria such as the dangerous *Escherichia coli* O157:H7.

Courtesy of the USDA Agricultural Research Service. Photo by Brian Prechtel.

Finishing diet The diet fed to livestock animals immediately prior to slaughter.

Hormonal growth promotants (HGPs) Hormones administered to livestock to promote weight gain prior to slaughter.

Gastronomy Point

Kobe Beef The Tajima-ushi breed of Wagyu cattle is well known because it is from this breed that Kobe beef, a delicate beef known for its desirable flavor and tenderness, is produced.

Green Point

Natural Cattle Natural cattle are not administered antibiotics or hormones at any time after birth or before slaughter, but they are still vaccinated to prevent liver abscesses and respiratory and clostridial diseases.

In the United States, most veal is raised in Wisconsin, Indiana, Michigan, Ohio, New York, and Pennsylvania. Note that these are also the states where many dairy cows are raised.

Because calves used for veal are taken to market at an early age, these animals primarily consume milk-based diets or milk replacers. Milk replacers come in three formulas: a starter, a grower, and a finisher. The starter formula is higher in protein than the finisher feed, but both feeds contain approximately 18% of calories from fat. Veal is lighter in color than beef because milk replacers are low in iron, which lowers the iron content of the meat and lightens the color of the final product. Ideally, the calves will gain 2.5 pounds per day until they reach 375 to 475 pounds; at this weight, they can be brought to market.

The conditions under which veal calves are raised have received much scrutiny in recent years; however, the American Veterinary Medical Association has worked closely with the industry to develop guidelines for the production and humane care of these animals. Although the calves are separated from their mothers within 24 hours after birth, they do receive their mothers' colostrum to protect them against disease. Once calves are separated from their mothers, they are placed in individual stalls where they have adequate room to stand up, lie down, and groom themselves. They are separated from other calves by a small partition that allows them to partially see each other. The benefit of separating these young animals is that this practice limits the spread of disease and keeps them from being stressed by other animals. The stalls are normally controlled at 60–70°F (15.5–21.1°C) for the first 2 weeks after birth; at that point, the temperature is lowered to 55°F (12.7°C).

The per capita consumption of veal is considered high in the United States, at 0.3 pound per capita annually. Other countries that consume large amounts of veal include Uruguay, Argentina, Australia, Brazil, and New Zealand. Veal was first described in ancient Roman recipes, and by the Middle Ages, references to veal were seen in many dishes in France and England. In some cultures, veal is considered a delicacy because of its tenderness and its light coloration. Countries with large populations of Hindus, such as India, have a low per capita consumption of these beef and veal products, primarily because Hindus consider cattle to be sacred and prohibit their consumption.

Innovation Point

CLA in Milk Increasing the amount of conjugated linoleic acid (CLA) in the milk replacer can increase the amount of CLA in the veal after slaughter. This makes the final veal product higher in this essential fatty acid, which has been associated with health-protective effects.

Lamb

Although the typical American eats only 0.8 pound of lamb annually, this meat originates from one of the oldest domesticated meat species. Lamb is a common main entrée in the Middle East and is widely consumed in Arab countries, North Africa, central Asia, and northern India. In the Middle East and Asia, lamb often is served along with spiced rice or rice pilaf. In northern Africa, it is commonly served alongside couscous (a wheat product). Currently, in the United States, Americans consume 0.6 pound of lamb and mutton per person annually.

The palatability and characteristics of sheep meat are highly dependent on the age of the sheep. Meat from young sheep—lamb—is commonly marketed from animals between 4 and 12 months of age. The biological point at which a sheep can no longer be marketed as a lamb is when the animal gets its first pair of permanent teeth, which usually occurs around 1 year of age. Meat from older sheep, also known as mutton, hog, or hogget, remains suitable for human consumption; however, mutton tends to be tougher and to have a much stronger, and often less desirable, flavor than lamb.

Young lambs are usually weaned from their mothers to diets of hay and fortified feed. Some lambs can be fed special diets to produce unique

flavors, such as those in France that graze in salt marshes to produce saltier meat. Immediately prior to slaughtering, most lamb will be transferred to a feedlot and transitioned to a nutrient-dense finishing feed. While in the feedlot, lambs may be given growth-promoting hormones through tags on the lambs' ears. Lambs that receive such hormones require a 40-day holding period prior to slaughter. Similarly, antibiotics may be administered to lambs; as with the waiting period for hormones, there is a holding period—established by the U.S. Food and Drug Administration (FDA)—between the time of antibiotic administration and the time of slaughter. This holding period ensures that residues from the antibiotic have sufficient time to exit the animal before its slaughter and that the residues are not consumed by humans.

At the time they are brought to market, most lambs weigh approximately 120 pounds and provide 60 to 72 pounds (inclusive of bone) of retail cuts. Lamb fat, which also can be harvested from the carcass, is not traditionally consumed in Western cultures, but it is frequently used in the manufacture of tallow candles.

Pork

In December 2015, the U.S. Department of Agriculture (USDA) estimated that there were more than 68 million hogs and pigs in the United States.³ Nearly one-third of the American hog and pig inventory is located in Iowa, while North Carolina, Minnesota, Illinois, and Indiana are also top pork-producing states.⁴ The United States is the largest exporter of pork and pork products in the world, exporting more than 4.73 billion pounds of pork in 2014.⁵ Per capita pork consumption is highest in countries such as Denmark, Spain, Germany, and Hong Kong.

Pork is the meat that comes from hogs, which are the modern-day, domesticated version of the wild boar. Hogs were first domesticated for food consumption in the Middle East shortly after the domestication of sheep. The ancient Greeks and Romans were known to have cherished suckling pigs, or young hogs that had not been weaned from their mothers, as a fine dining delicacy. Romans also enjoyed cured pork products, such as ham.

Hogs are not indigenous to North America, but rather were introduced by Spanish explorers in the 16th century. Pork quickly gained in popularity, and, in part because of its long shelf-life when preserved, it became one of the most popular meats in the American diet. Today, a variety of hog breeds are raised around world, but in the United States popular breeds include the Yorkshire, Duroc, and Poland China.

Pork can originate from pigs or hogs of different sexes. Animals up to 4 months of age are considered to be pigs; animals older than 4 months are considered to be hogs. Among females, gilts are young females that have not given birth, and sows are females that have either been pregnant or have previously given birth. Among males, barrows are males that have been castrated prior to sexual maturity, staffs are males that have been castrated after sexual maturity, and boars are males that have never been castrated. Hogs reach sexual maturity around 6 to 8 months of age, and they are typically brought to market between 6 and 12 months of age.

Most pigs and hogs are raised on commercial hog feeds that are composed of proteins from soybean meal, fish meal, milk, and meat by-products. These feeds are also high in carbohydrates, which primarily come from corn. Vitamin B₁₂ and other supplements may be added to the feed to help promote growth and weight gain. Over the years, hogs have been bred to be leaner and less fatty than their ancestors, largely because of the decreased market demand for pork lard.

Gastronomy Point

Suckling Lambs In some European and Middle Eastern countries, suckling lambs, or lambs that have been fed only their mother's milk, are marketed and sold as a delicacy.

At the time of slaughter, most hogs weigh 175 to 240 pounds. Although it does tend to take smaller-birth-weight pigs longer to reach market weight, the quality and palatability of pork are not affected by the animal's birth weight.⁶ Smaller, younger hogs are used to produce fresh pork, which is tender and has a mild flavor. Older, larger animals are used for cured meats, such as bacon and ham. Overall, approximately one-third of pork meat is marketed as fresh pork, or "porkers"; the rest is marketed to consumers in cured forms, such as sausage, luncheon meats, and ham. The by-products of the hog are also retained and marketed, reducing the amount of leftover waste. For example, manufacturers often purchase pork skin and use it in the production of gelatin.

After slaughter, the hog carcass is "dressed," and all edible organs are inspected by a trained veterinarian. The carcass is then dissected into its major cuts (i.e., hams, loins, bellies, back fat, shoulder) prior to being shipped to meat distributors.

Pork is consumed in many countries around the world. In the United States, per capita annual consumption is estimated at nearly 46 pounds of pork. In areas such as China, Southeast Asia, and Polynesia, pork is also considered a staple meat and is commonly consumed. In contrast, Japan is not a large consumer of pork products, but it does import a substantial amount of pork from the United States. Because Judaism and Islam discourage the consumption of pork, perceiving this meat as being "unclean," countries with large Jewish and Muslim populations do not have a large per capita consumption of pork products.

Green Point

Stomachs Unlike cattle, whose stomachs have four parts, pigs and hogs have a single-part stomach. As a result, they do not produce as much digestive gas emissions as cattle do. Pork production accounts for less than 1% of the total U.S. greenhouse gas emissions.

Special Topic 7.1

H1N1 or "Swine Flu"

Zhanglin Kong, MS

H1N1 influenza (swine flu) was a global pandemic that first caused illness in Mexico and the United States in 2009. In April 2009, 59 deaths were caused by H1N1 in Mexico City alone. On June 11, 2009, the World Health Organization (WHO) raised the worldwide pandemic alert level to Phase 6 to signal a global pandemic of this novel influenza A strain.¹ This action was a reflection of the spread of the new viral strain and its potential for harm, rather than the actual number of deaths, which were far fewer than those caused by regular seasonal flu.

H1N1 influenza was initially named "swine flu" to indicate a swine origin. In reality, transmission of the virus from pigs to humans is not common and does not always lead to human influenza, often resulting only in the production of antibodies in the blood. Although the genes of the H1N1 virus comprise a combination of genes most closely related to North American swine-lineage H1N1 and Eurasian swine-lineage H1N1 influenza viruses, investigations of initial human cases did not identify exposures to pigs. It became apparent that this new virus was circulating among humans and not among U.S. pig herds, which means that H1N1 flu is not a foodborne disease and is not caused by eating pork or pork products.²

The symptoms of H1N1 flu are very similar to the symptoms of a regular flu strain—namely, fever, cough, sore throat, runny or stuffy nose, body ache, headache, chills, fatigue, and sometimes vomiting or diarrhea. The H1N1 virus is spread mainly through the coughs and sneezes of infected people.³

Vaccine and Antiviral Treatment

In the United States, the Centers for Disease Control and Prevention and local animal and human health officials work closely on epidemiologic investigations, vaccine development, communications, and other responses.¹ Vaccination offers protection from the H1N1 flu. Producing the vaccine involves a number of complicated steps.²

- Obtain a high yield of virus by growing it in chicken eggs.
- Purify the virus particles to make vaccine.
- Distribute the vaccine to targeted individuals via hospitals and clinics.

Target individuals for initial focus when a vaccine supply is limited are (1) people who are most likely to develop illness or spread infection and (2) people who account for the majority of severe illnesses and deaths. When the H1N1 vaccine was first developed, pregnant women, children, adults younger than age 24, adults with certain chronic health conditions or compromised immune systems, and healthcare and emergency medical services personnel were prioritized to receive the vaccine. At the same time, infected people were suggested to avoid close contact with others, especially those who might easily get the flu.³

Fortunately, these vaccines are now readily available and are distributed widely among the general population who receive seasonal flu vaccines.

Lessons from the H1N1 Pandemic

As the first pandemic that emerged in the 21st century, the H1N1 outbreak taught us some important lessons:^{4–7}

- The current methods of vaccine production in the United States are not efficient enough to provide an adequate response to a pandemic. This shortcoming exists not only because very little vaccine-manufacturing capacity is left in the pharmaceutical industry, but also because there is a lack of official channels for pandemic-level vaccine distribution.
- Information sharing in the future must be more effective. The distrust caused by the perception that officials overreacted to the H1N1 pandemic needs to be overcome. Cultural diversity and the timeliness, coordination, and consistency of message delivery should be considered.
- Social media reports should be given close attention because they tend to interpret data to extremes.

References

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Physical and Chemical Properties of Meats

Structure of Meats

Cuts of meat from cattle, lamb, and pork have similar components. The main component of meat—and what most people desire when they consume meat—is the actual muscle tissue. Muscle tissue is roughly 75% water, 18% protein, 4–10% fat (depending on the animal and the cut), and minimal carbohydrate. In addition to the muscle tissue, meat cuts include bone (including bone marrow), connective tissue, and fat.

Muscle

Because most consumers select their meat based on the cut's muscle tissue, it is important to understand how muscle tissue is constructed. Most of the muscle tissue is actually water. When heated, the size of the meat will shrink

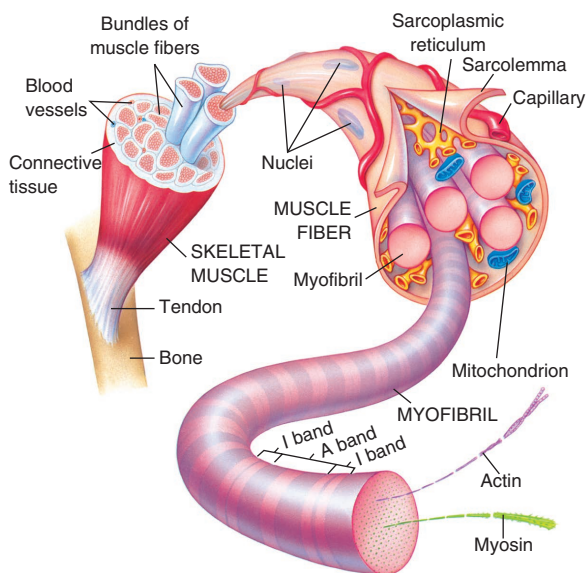


FIGURE 7.4 Muscle structure.

Myosin Thick filament in muscle fibrils that binds with actin in muscle contraction and relaxation.

Actin The thin filament in muscle fibrils that binds with myosin in muscle contraction and relaxation.

Collagen Connective tissue found in meats that will break down and form gelatin under moist heat.

Elastin Connective tissue found in meats that must be physically removed or trimmed prior to consumption of the meat product.

in size, partly due to the evaporation of the water from the muscle tissue. Shrinkage is also the result of actions of the muscle proteins.

Muscle proteins range from large to a small. Muscle tissue, in general, is composed of individual muscle cells, or muscle fibers. As shown in **Figure 7.4**, each muscle cell is surrounded by a membrane, called the *sarcolemma*, and contains a fluidlike center, called the *sarcoplasm*.

Inside the muscle cell are the muscle myofibrils; each muscle cell can contain 2000 or more muscle myofibrils. The muscle myofibrils play an important role in determining the taste of the muscle tissue. In particular, small muscle myofibrils give the muscle a smooth, delicate mouthfeel.

Within the muscle myofibrils are regions called *sarcomeres*, which house the two main muscle proteins, myosin and actin. **Myosin** is the thick filament found in muscle tissue; **actin** is the thinner filament. During muscle contraction, adenosine triphosphate (ATP) and calcium cause myosin and actin to come together and form cross-bridges. The resulting, shortened state is called actomyosin; the sarcomere will remain in this shortened state until it becomes relaxed again.

Bone

Another component of meat is bone. The presence of bones in meat is especially useful when determining the cut of meat and where the meat originated. The size of bones can also help determine the age of the animal at slaughter and can be an indicator of meat tenderness. Both yellow and red bone marrows also contribute to the flavor of meat. For this reason, chefs often choose to cook bone-in meats instead of boneless cuts. Bones and their bone marrow are also commonly used in the making of broths and stocks to add flavor.

When purchasing meat cuts with bones, the price per unit weight is typically lower than the price per unit weight of boneless cuts. Because bones are not consumed and can sometimes weigh more than the muscle that is consumed, the price difference between bone-in and bone-out cuts needs to be considered when purchasing meats.

Connective Tissue

Meats also are composed of connective tissues, which hold the meat together. The amount of connective tissue found in meats will have a significant impact on the tenderness of the meat. High quantities of connective tissue cause most meats to become tough and less tender.

Connective tissues are visible to the naked eye as a white, tough substance. One of the more abundant connective tissues found in meat is **collagen**, a substance found within and around muscle tissue. When exposed to warm, moist heat, collagen will turn into a gel (gelatin). Collagen is composed of the amino acids proline, hydroxyproline, and glycine. This connective tissue prevents the stretching of muscle and becomes more tightly cross-linked as the animal ages. Reticulin is a small connective tissue fiber made of collagen that surrounds and protects muscle cells.

Elastin is another, less abundant type of connective tissue found in meats. As its name implies, elastin is more elastic and flexible than collagen. Physiologically, elastin allows muscle and other organs in the body to return to their original shape after stimulation and contraction; however, the presence of elastin contributes to toughness of meat and often makes the meat less palatable.

Fat

Adipose tissue, or fat, is another component of meat that must be considered during purchasing and preparation. Fat can account for 4–10% of meat content, depending on the animal and the cut of meat. Fat covers the muscle

tissue and can also be located within the muscle tissue (i.e., intramuscular fat). Fat that covers the muscle tissue is desirable because it helps the meat to retain moisture. Intramuscular fat contributes to the **marbling** of the meat; highly marbled meat tends to be juicy and has a more palatable flavor than its leaner counterparts (**Figure 7.5**).⁷

The amount of fat found in cuts of meat varies widely. Older animals tend to have less fat, so they do not produce meat as juicy and tender as that from younger animals. In addition, the nutritional composition of the animal's diet can affect the fat content of the meat. Beef fat is often extremely soft due to the high concentration of polyunsaturated fatty acids found in beef finishing feed. Animals with high-calorie finishing diets tend to have more fat and usually produce more tender meats. Interestingly, the carotenoid content of the finishing diet affects the color of fat in the meat product. Animal feed containing high amounts of carotenoids will cause the fat to turn yellow; animals fed carotenoid-deficient diets will usually have fat that is white in color.

Meat cuts from lean animals are extremely tough and difficult to chew. Likewise, cuts of meat from muscles that are involved in regular exercise, such as the leg muscles, are tougher than muscles that perform little or no exercise and that contain higher amounts of fat. Genetic mutations can also affect the tenderness of meat. In beef, an addition in the myostatin gene decreases the fat content of the meat, which results in a less desirable flavor of the final meat product (**Figure 7.6**).⁸

Pigments

Meats contain pigments that give the cut a unique coloration. The main pigments in beef, lamb, and pork come from the proteins hemoglobin and **myoglobin**. Hemoglobin has a higher molecular weight than myoglobin. Despite having a smaller molecular weight, myoglobin is important because it contributes to the redness of meat. Myoglobin is found in larger quantities in beef and lamb than in poultry and fish, which explains why beef and lamb are considered “red meats” and poultry and fish are considered “white meats.”

The pigments found in meat contain both iron and heme. Iron is particularly important because when this element changes its chemical state by binding to oxygen, the color of the meat is immediately affected. By itself, myoglobin contains an iron molecule in the ferrous state (Fe^{2+}); meat containing this state of iron exhibits a purplish-red color. When meat is cut and exposed to oxygen, myoglobin and oxygen form a compound known as **oxymyoglobin**, which causes the meat's color to change to bright red. Excessive exposure to oxygen causes water to bond with iron, so that the iron turns into its ferric state (Fe^{3+}). When this happens, the oxymyoglobin is transformed into **metmyoglobin**, which gives the meat a brownish-red color. Although this brownish-red color does not indicate the meat is old or spoiled, it is usually undesirable to the consumer. For this reason, food manufacturers take caution when packaging meats and use techniques such as vacuum packing to reduce the raw meat's exposure to oxygen.

The pigmentation of meat can be affected by other factors besides oxygen exposure. Muscles that are frequently exercised have a higher oxygen demand and a resulting cherry-red color. The species of animal and the animal's age affect the color of the meat as well. Beef has a darker color than veal because it is slaughtered at an older age and contains more myoglobin. The addition of preservatives, particularly sodium nitrite, also can affect the color of meat. During preservation, sodium nitrite is converted to nitric



FIGURE 7.5 Food technologists analyze the intramuscular fat, or marbling, of beef slices. It usually appears as a series of small white flecks in the cut of meat. Marbling helps meat retain moisture during cooking and contributes to mouthfeel.

Courtesy of the USDA Agricultural Research Service. Photo by Stephen Ausmus.

Marbling Fat interspersed throughout muscle tissue.

Myoglobin Primary pigment found in meats.

Oxymyoglobin Compound formed when the myoglobin pigment in a meat comes into contact with oxygen, causing the meat to become bright red.

Metmyoglobin Compound formed when myoglobin is exposed excessively to oxygen and the iron converts to the ferric state, causing the meat to become brownish-red.

Nitric oxide myoglobin Pigment found in cured meats that causes the meat to turn pink.

Lactic acid A biological compound that builds up in animal carcasses after slaughter, reducing the pH of the meat.

Green Point

Transportation for Slaughter Some livestock producers do not transport their animals prior to slaughter, which keeps the animal from becoming stressed. An additional benefit of this practice is that it reduces greenhouse gas emissions resulting from the transportation process.



(a)



(b)

FIGURE 7.6 A. Beef with no copies of the inactive myostatin gene. This meat has more marbling than meat from cattle with the myostatin gene. **B.** Beef with two copies of the inactive myostatin gene. This meat is leaner and has less marbling than meat from cattle with fewer or no copies of the myostatin gene.

Courtesy of the USDA Agricultural Research Service. Photo by M.A.R.C.

oxide, which binds with myoglobin to form **nitric oxide myoglobin**. Nitric oxide myoglobin is the bright red color often seen in uncooked processed meats, such as sausage, and it causes the preserved meat to turn pink when heated or cooked.

Slaughtering and Aging

The conditions under which an animal is slaughtered will significantly impact the quality of the meat. Animals should be slaughtered under conditions that are humane and not stressful to the animal. Ideally, the animal will be brought to market at a time when its muscles are loaded with glycogen and when the animal has not recently been exercised or excited. After slaughter, the animal is no longer taking in oxygen, so aerobic respiration will cease. As a result, the animal's glycogen stores will gradually convert to pyruvate and eventually to **lactic acid**. The buildup of lactic acid proceeds slowly as the animal carcass begins to enter a state known as rigor mortis. During rigor mortis, which occurs approximately 6 to 24 hours after slaughter, the presence of lactic acid lowers the pH of the meat to a desirable level of 5.4 to 5.8. Maintaining this low pH allows the meat to bind water and retain moisture, and these desirable conditions will prevent carcass meat from becoming dry.

Live export of animals to the slaughterhouse may induce stress in animals, causing them to exhaust their glycogen prior to slaughter. Thus, soon after death, lactic acid will build quickly, and the pH will drop prior to the onset of rigor mortis. As a result, the pH during rigor mortis will exceed 5.8, and the meat may develop an undesirable sticky texture and brownish-purple color. To avoid this outcome, some producers do not transport their cattle to a slaughterhouse but instead slaughter their livestock in areas close to where the cattle are already being held.

As the animal carcass passes through rigor mortis, it is common for the meat to be hung from a beam. This hanging allows the meat fibers to be stretched, which promotes a more tender end product. Likewise, many carcasses are aged after rigor mortis. Aging can be done by leaving the carcass hanging in a temperature- and humidity-controlled environment (dry aging) or by vacuum-packing the carcass in its own juices (wet aging). Some cuts of beef, such as the short loin, may have decreased yields and increased cutting times as a result of dry versus wet aging; however, the palatability of both types of end products remains similar.⁹ Both dry and wet aging processes promote tenderness and flavor development, and these processes can be ongoing for up to 4 weeks post slaughter.

Tenderizing Meats

Prior to cooking, tenderizing agents can be added to meats to help further break down connective tissue and make the final product less tough. The two most commonly used chemical tenderizing agents are papain and bromelain. Both of these enzymes originate from plant sources: Papain comes from the papaya fruit, whereas bromelain comes from pineapple. These enzymes act by breaking down collagen to produce a more tender texture. Like all other proteins, these enzymes become denatured and inactive when heated to extreme temperatures, but they are also inactive at room temperature. Papain is most active at temperatures around 151°F (66°C).¹⁰ Bromelain becomes active at 104°F (40°C) and is deactivated around 149°F (65°C). Regardless of which enzyme is used, the meat should be poked with a sharp fork or spear (Jaccard meat tenderizer) prior to

tenderizing so that the enzymes can reach the inner portions of the meat cut. Otherwise, the outer portions of the meat will be tender, and the inner portions will remain tough.

Mechanical tenderization is another means by which meat can be tenderized. Mechanical tenderization may occur while the entire meat carcass remains intact, or it may occur once the meat has been cut into pieces. A commercial meat tenderizer is a large piece of equipment with blades and needles that cuts through excessive connective tissue. Other pieces of commercial equipment may cube the meat into smaller pieces with shorter segments of connective tissue. Meat carcasses and smaller cuts can also be pounded with a meat mallet to further break down the remaining connective tissue. As a final step, carving meat against the grain (the muscle fibers) will help to disrupt any remaining chunks of connective tissue.

One problem with mechanical tenderization is that this process can jeopardize food safety and increase the risk of foodborne illness. If bacteria are found on the outside of the meat, the process of mechanical tenderization may relocate those bacteria to inside the meat. Because some meat products are served at an internal temperature that does not kill the bacteria (i.e., some meats are served rare or medium rare), the bacteria may then cause the consumer to develop a foodborne illness. Such was the case in 2009 when people from 16 states became infected with *E. coli* O157.¹¹ This outbreak was traced back to mechanically tenderized steaks and led to the recall of more than 248,000 pounds of beef. The USDA now requires mechanically tenderized meats to be labeled as such.¹²

Heating Meats

The addition of heat to meat will cause numerous changes, particularly to meat proteins. The shape, composition, and length of proteins determine characteristics such as flavor, juiciness, and tenderness of the meats. As meat is heated, the proteins, or muscle fibers, become denatured and decrease in length. This process causes a reduction in the water-binding capacity of the protein, thereby limiting the amount of liquid that the fibers will be able to bind. The application of heat also dehydrates the myosin, ridding the meat of water already retained and making the final product less juicy than its original uncooked state. In addition, heat causes the denatured proteins to cross-link and coagulate, giving the meat a tough and less tender texture. Meats can be cooked to a wide range of temperatures or doneness; varying degrees of doneness are provided in **Table 7.1**.

TABLE 7.1 Cooking Temperatures for Various Degrees of Doneness in Beef Steak	
Degree of Doneness	Temperature
Rare*	< 145°F (< 63°C)
Medium rare*	145°F (63°C)
Medium	160°F (71°C)
Well done	170°F (77°C)

*Consuming rare meats is not generally recommended due to the risk of bacterial contamination and foodborne illness.

Data from Cattlemen's Beef Board and National Cattlemen's Beef Association.

Connective tissues, such as collagen, also begin to break down when exposed to heat. Exposure to moist heat causes the hydrogen bonds in collagen to break, forming gelatin. This conversion of collagen to gelatin is essential when tenderizing tough meats such as beef pot roast. If the gelatin is allowed to seep into the meat drippings, these drippings can be chilled, and the resulting gel can be seen by the naked eye. Tough cuts of meat are ideally prepared using a slow, moist heat so collagen can be converted to gelatin without overheating and toughening the meat’s protein. The other connective tissue found in meats, elastin, is not altered by heating. Thus, meats with elastin will remain tough throughout heating, and the elastin must be physically removed before consumption.

Altering the pH of the meat can cause changes in meat texture during cooking. For this reason, meats may be soaked in acidic marinades for several hours before cooking. The acid in the marinade tenderizes the meat as well as imparts unique flavors that will be retained throughout cooking.

Freezing Meats

Freezing meats and meat products enables the consumer to keep the food for a longer period of time than when simply keeping the foods in the refrigerator. **Table 7.2** shows the estimated amount of time that a meat can be kept in the frozen state.

When freezing a meat, quick, low-temperature freezing is imperative. Because water freezes at a different temperature than the meat, water can separate from the protein, and once the water does begin to freeze (usually around 28–29°F [–2.2 to –1.7°C]), it forms large crystals that break apart the surrounding tissues and result in a low-quality end product.

The freezing of meats also can result in drip losses when the product is eventually thawed. Again, if water is allowed to separate from the other proteins in the meat, it will be lost when the meat is thawed, resulting in a less

TABLE 7.2 Cold Storage Estimated Storage Times for Beef, Veal, Lamb, and Pork		
Meat	Shelf Life at 40°F (4°C)* or Below	Shelf Life at 0°F (–18°C) or Below
Ground meats	1–2 days	3–4 months
Chops Roasts Steaks	3–5 days	4–6 months (chops) 4–12 months (roasts) 6–12 months (steaks)
Leftovers, cooked meat	3–4 days	2–6 months
Bacon	7 days	1 month
Sausage (raw)	1–2 days	1–2 months
Soups and stews (with meat)	3–4 days	2–3 months
Luncheon meat	3–5 days (opened package or sliced deli) 2 weeks (unopened package)	1–2 months

*ServSafe recommends 41°F (4.4°C).
Reproduced from U.S. Department of Health and Human Services, Food Safety.gov.

juicy final product. The freezing of meats may impact their overall tenderness once thawed and prepared; however, investigation into this issue has not always produced consistent results.^{13–16}

For large-scale facilities where meat carcasses are stored frozen, specific conditions should be met. Freezer temperatures should be kept around -5°F (-20°C), and air velocities should be maintained at 500–1000 feet per minute.¹⁷ These conditions will bring the temperature of meat down quickly enough to prevent formation of ice crystals and retain a high-quality product. Additionally, when meats are cooled quickly, the potential for bacterial growth is minimized.

Preserved and Processed Meats

Agriculturalists and food scientists have mastered the art of processing meats to produce products with various flavors and textures desirable to the consumer. Ham, corned beef, pastrami, bacon, and hot dogs are all commonly consumed meats that undergo extensive processing. **Curing** is one of the most common techniques used in meat preservation. Curing includes processes such as salting, smoking, and drying.

When curing a meat, several agents, such as sodium chloride (salt), sodium nitrite, sucrose (common table sugar), and ascorbates, are usually dissolved in water to form brine, which is the curing solution:

- Sodium chloride imparts a distinct flavor to the final product, and reduces the amount of free water available. Reducing the food's water content also limits bacterial growth, thereby preserving the food. Note that the salts used in curing may contain trace amounts of copper or other metals, which can speed up oxidative rancidity in the final product. For this reason, cured meats need to be handled carefully and stored properly.
- Sodium nitrite functions as an antioxidant to prevent oxidative rancidity. It can also protect against botulism, a foodborne illness, by preventing the growth of *Clostridium botulinum*, a spore-producing bacterium. Because excessive nitrite can be toxic, the USDA's Food Safety and Inspection Service (FSIS) regulates the amount of nitrite that may be added to a product.
- Sucrose is added during curing to reduce the salty flavor imparted by sodium chloride. If added in appropriate amounts, sucrose also can cause a desirable brown coloration on the final cured product.
- Ascorbates, another group of preservatives, are reducing agents; they reduce nitrites to nitric oxide. After reduction, nitric oxide will combine with the metmyoglobin pigments and produce the pink color (nitrosyl hemochrome) commonly associated with cured meats.

The conditions under which a meat is cured depend on the size of the meat cut and the temperature under which it is cured. Large meat cuts, such as hams, need to be cured for an extended period of time because it takes a while for the brine to penetrate the thick cut of meat. In addition, temperature affects curing. All curing should take place at temperatures less than 40°F (4.4°C) to minimize bacterial growth; however, if the temperature is too far below 40°F (4.4°C), the desired chemical reactions can be slowed or completely halted unless more chemicals are added. In general, a piece of meat cured in brine should take about $3\frac{1}{2}$ to 4 days per pound to undergo

Curing Preservation technique used in making meat products such as sausage and frankfurters.

the curing process if the temperature is held at 36–40°F (2.2–4.4°C). The speed of this process can be increased dramatically if the brine is injected directly into the meat; in this case, the amount of time required to finish curing a ham may be decreased to as little as 24 hours. To cure bacon, brine is injected directly into the pork belly; within a few minutes, the curing process is finished.

After the meat product has been subjected to the curing agents, the product may be smoked in a commercial smoke box or smokehouse. Wood logs and sawdust from trees such as oak and hickory are commonly used when smoking hams, because the phenols and carbonyls produced by smoking impart a distinct and desirable flavor to the final product. The process of smoking must raise the internal temperature of the product enough to destroy *Trichinella spiralis*, a parasite commonly found in hogs. Note that curing or smoking alone will not kill the parasite; instead, it is the high temperature that kills the parasite. Individuals who make their own sausage or jerky should therefore be careful when producing these products, as the homemade versions have been the source of *Trichinella spiralis* outbreaks in the recent past.

Hams that have been cured and smoked are considered to be precooked hams. Although they are “cooked,” the consumer should still reheat these hams to at least 140°F (60°C) prior to consumption.

Sausage is another commonly consumed processed meat product. The meat used to make fresh sausage originates from low-grade cattle and hogs. Under U.S. government regulations, sausage cannot have a fat content greater than 50%. When making fresh sausage, the meat is ground and combined with other herbs and seasonings, such as salt, pepper, and sage. The ground product is then stuffed into a natural or synthetic casing. Natural casings are usually made from the lining of sheep intestines, whereas synthetic casings may be made from food-grade plastics. After being stuffed, fresh sausage should be prepared and stored at around 32°F (0°C) to limit bacterial growth and prevent oxidative rancidity.

Frankfurters, commonly known as hot dogs, are another type of sausage consumed widely in the United States and throughout the world. This processed meat is typically made from beef and pork, although due to consumer demand some frankfurters are now made from poultry and soy products. Like fresh sausage, frankfurters are typically combined with other seasoning agents, such as pepper, mustard, and garlic, to give the final product a desirable flavor. Unlike fresh sausage, though, frankfurters are cured and smoked before being packaged and sold. The curing process involves the addition of nitrites and ascorbates, a process similar to that seen in the preparation of ham. Fat and other emulsifiers may sometimes be added before the meat slurry is pumped into its casing and smoked in chamber. Once packaged, the final product is kept at about 32°F (0°C). Unless frozen, the product will eventually spoil and become slimy or turn green. The green color seen on some expired frankfurters or bologna is the result of a chemical reaction between hydrogen peroxide produced by bacteria and the pigment nitrosohemochrome found in the meat.

Because of the public interest in lowering the fat content of meats and meat products, many processed meats are now made with leaner meat and have bulking agents added to the meat slurry instead of fat. These bulking agents may be protein-containing ingredients, such as whey concentrates, or carbohydrate-based ingredients, such as fiber, gums, and modified starches.¹⁸

While processed meats have significant appeal among consumers, health professionals and medical organizations often discourage consumption of processed meats due to their association with cancer. In October 2015, the World Health Organization's International Agency on Cancer Research (IACR) officially announced that processed meat had been classified as a Group 1 carcinogen.¹⁹ The organization based its decision on the body of scientific evidence suggesting that colorectal cancer can be caused by consumption of processed meats. The proposed mechanism by which processed meats cause cancer is rooted in the formation of nitrosamines. Specifically, the nitrates and nitrites found in processed meats are converted to nitrosamines in the human body, and nitrosamines then damage cellular DNA, a process involved in cancer development.

In the same announcement, the IACR also classified red meat as a Group 2A carcinogen, meaning that consumption of red meat is probably carcinogenic to humans. These statements drew harsh criticism from the meat industry, many of whom questioned the scientific validity of these claims. Nonetheless, the statements have remained in effect, and many clinicians continue to counsel high-risk patients against consuming high amounts of processed meats and other meat products.

Meat Alternatives

Due to personal preference, health issues, and food and environmental concerns, many people have turned to using meat alternatives. Soy-based alternatives, particularly **textured soy protein (TSP)**, which is also known as *textured vegetable protein* (TVP), is commonly marketed to consumers who avoid eating animal-based products. When making TSP, soy flour or soybeans are defatted and their proteins isolated.²⁰ The protein-rich concentrate produced by this process is then dehydrated, and the final product is shelf-stable for nearly 12 months when stored in an airtight container.

Nutritionally, TSP is an excellent meat alternative due to its high protein content. By weight, TSP is at least 50% protein; furthermore, the proteins found in TSP are complete because they contain all of the amino acids that the human body cannot synthesize itself (i.e., indispensable amino acids). When producing foods with TSP, processing must proceed carefully and under controlled conditions. Otherwise, products containing large amounts of TSP may develop an undesirable "beany" flavor. The development of this flavor and its accompanying odor results from the oxidation of unsaturated fatty acids in the TSP.²¹ Because the development of these characteristics will make the final food product unpalatable, food scientists may limit the amount of TSP they add to meat substitutes and meat analogs, and they may also experiment with the cooking techniques used to prepare products made with TSP. For example, one study found that the majority of consumers enjoyed chicken- or shrimp-flavored TSP products when they were fried, whereas fewer than one-third of the consumers liked the same products when they were baked.²²

In food science, TSP also can be used as a **meat extender**. Because of its high protein and relatively low-fat content, TSP usually has a more favorable nutrition profile than high-fat, high-cholesterol meats. Some processed meat products, therefore, may have their fat content lowered by replacing some portion of the meat with TSP. In addition, TSP often is cheaper than meat so food manufacturers may incorporate TSP into meat products as a means to lower the final product's overall cost.

Gastronomy Point

Salami Salami, a cured meat, has been widely consumed in southern European cultures for centuries due to its shelf stability.

Textured soy protein (TSP)

A protein-rich meat alternative made from defatted soy flour or soybeans.

Meat extenders Protein substances added to meat; sometimes used synonymously with "meat fillers," which are usually carbohydrate substances.

Phytonutrient Point

Isoflavones Textured soy protein contains isoflavones—phytonutrients that are associated with the prevention of some types of cancer.

Green Point

Meat Alternatives Because textured soy protein comes from plants, much less energy is required for its manufacture and production compared to that required for the maintenance, slaughter, and processing of animals. Thus, meat alternatives often are considered to be more environmentally friendly than meat.

Special Topic 7.2

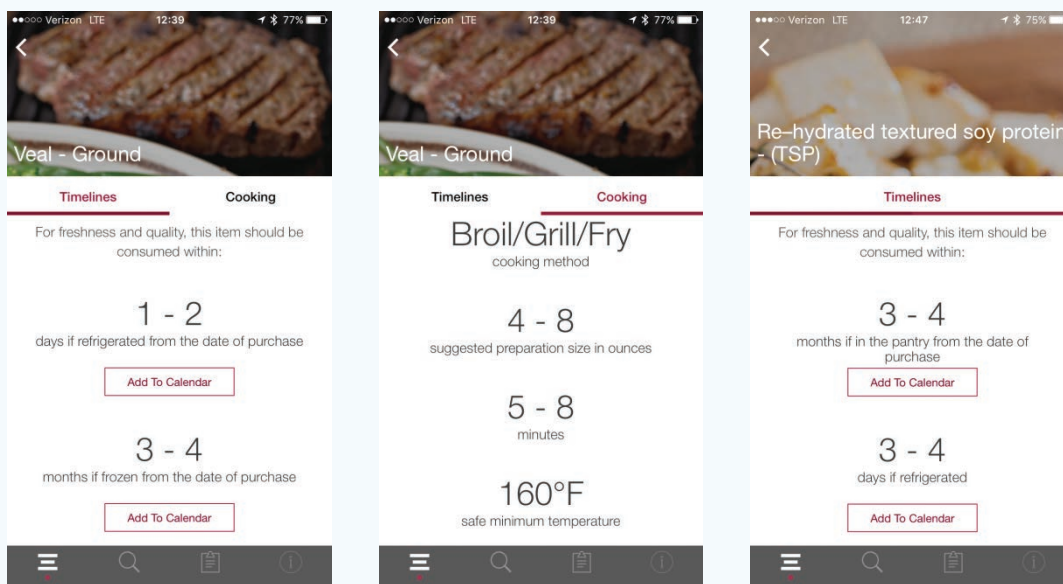
The FoodKeeper App

Courtney Winston Paolicelli, DrPH, RDN, LD, CDE

According to a 2014 report from the U.S. Department of Agriculture, nearly 31% of all food—some 133 billion pounds of food—goes uneaten and gets discarded annually in the United States.¹ Not only does this represent a loss of more than \$161 billion, but it also has significant environmental implications. To help combat such food waste and thereby reduce the negative environmental effects, the USDA has collaborated with Cornell University and the Food Marketing Institute to develop a no-cost, consumer-friendly app, appropriately dubbed “the FoodKeeper.”²

The main goal of the FoodKeeper is to provide accurate, consumer-friendly information about commonly consumed foods and beverages. In particular, the app informs consumers of the amount of time a particular food or beverage can be refrigerated or frozen before its quality and freshness may begin to deteriorate. Consumers can also use the FoodKeeper to determine preferred preparation methods and minimum cooking temperatures for various meats and meat products.

Consumers can find their foods or beverages using the main food categories listed on the FoodKeeper app's home page, or they can search for a specific item using a simple search tool. For each item in the database, the FoodKeeper has a timeline for when the item should be discarded, depending on whether the food is refrigerated or frozen. Consumers can then opt to add these dates to their calendars as a reminder to use the food before its quality and freshness date expires.



References

- 1 Buzby JC, Wells HF, Hyman J. *The estimated amount, value, and calories of postharvest food losses at the retail and consumer levels in the United States*. EIB-121. U.S. Department of Agriculture, Economic Research Service; Washington, DC: February 2014.
- 2 U.S. Department of Health and Human Services. FoodKeeper app. September 14, 2016. <https://www.foodsafety.gov/keep/foodkeeperapp/>. Accessed September 14, 2016.

Food Selection and Menu Planning

Meats are often the centerpiece of a meal, which other foods and beverages are chosen to complement. As such, meat should be selected carefully well in advance of the designated meal time, and an appropriate preparation and cooking plan should then be followed. The method by which the meat is cooked is highly dependent on the cut of the meat, so an understanding of the composition of various cuts of meat is imperative.

Cuts of Meats

Wholesale and retail cuts of meats vary widely in their fat, muscle, and connective tissue content. As a result, consumers must consider the overall composition of the meat when selecting the appropriate cut. In general, cuts from muscles that receive regular exercise will be leaner and tougher than those from areas on the animal that do not receive exercise.

Beef

In the United States, butchers divide cattle carcasses into two symmetric pieces, and then cut each piece in half. The front half, known as the forequarter, includes the chuck, rib, short plate, brisket, and foreshank. Common cuts such as stew beef, ribeye roll steak, rib roast, and beef brisket all originate from forequarter cuts. The back half of the carcass, known as the hindquarter, includes the short loin, tenderloin, flank, and round cuts. Many of the popular steaks, such as flank steak, top sirloin butt steak, tenderloin steak, and filet mignon, originate from the hindquarter region (**Figure 7.7**).

Veal

Because of the animal's small size, veal has many fewer cuts than beef or pork. The main primal cuts, or the first cuts from the whole carcass, include leg (round), sirloin, loin, rib, shoulder, foreshank, and breast. Because veal is slaughtered at a young age compared to other animals, most veal roasts contain a high amount of fat and, therefore, are extremely tender (**Figure 7.8**).

Lamb

Lamb has four primal cuts: shoulder, rack, loin, and leg. These are then broken down into several retail cuts typically seen in the grocery stores, including the neck, foreshank, breast/brisket, and flank. Most cuts of lamb are fairly tender and do not require the same amount of tenderization as corresponding cuts of pork and beef (**Figure 7.9**).

Pork

The American primal cuts of pork include shoulder blade, arm shoulder, loin, leg, and side. The loin is popular because the pork loin chop and roast originate from this area, as does the pork loin tenderloin and Canadian bacon. Spare ribs and bacon originate from the side primal cut, which is sometimes referred to as the “belly” of the hog. Although any region of the animal can be cured, the leg region of the hog is typically used to produce cured ham (**Figure 7.10**).

Choosing Healthy Cuts

Many consumers are interested in reducing their intake of saturated fat and, therefore, prefer lean and low-fat cuts of meat. Among trimmed beef cuts, a 3-ounce serving of flank steak, T-bone steak, or sirloin steak all meet government guidelines for “lean” meat (defined as having less than 10 grams total fat, 4.5 grams or less saturated fat, and less than 95 milligrams [mg] cholesterol per 100 grams and per the recommended amount customarily consumed). Top round roast and steak and 95% fat-free ground beef also meet these guidelines. The leanest cuts of veal include the sirloin, rib chop, loin chop, and leg cutlet. With only 2.98 grams of fat per 3-ounce serving, pork tenderloins are considered a health-conscious choice of meat as well.

Creating Well-Rounded Meals with Meats

It is important to balance a meal with additional side items that complement the flavor, temperature, and texture of the meat. For example, when meat is

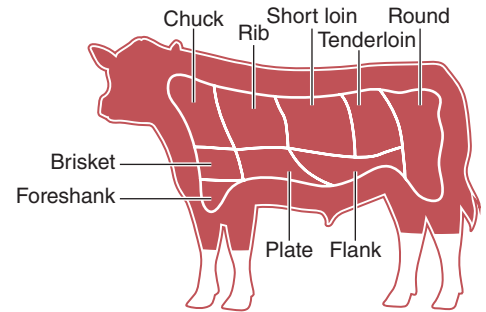


FIGURE 7.7 Standard cuts of cattle.

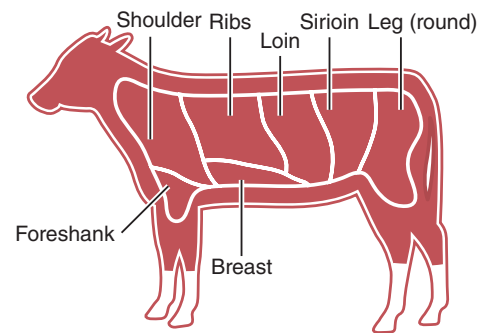


FIGURE 7.8 Standard cuts of veal.

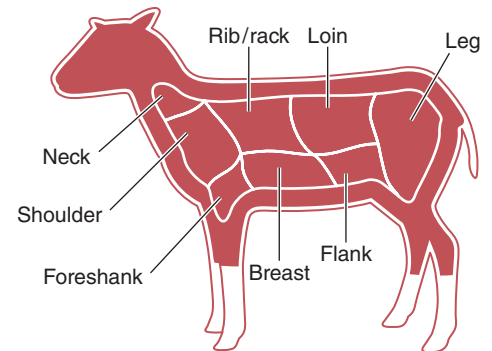


FIGURE 7.9 Cuts of lamb.

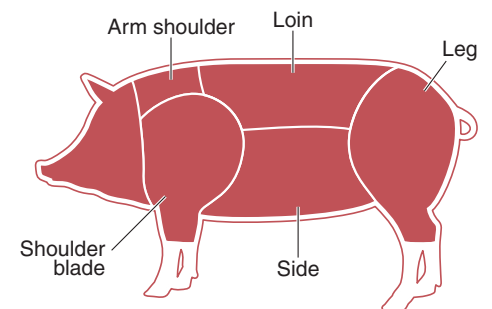


FIGURE 7.10 Cuts of pork.

Gastronomy Point

Yin and Yang In ancient Chinese culture, meals were created based on the yin and yang principles of balance. Meats, which were typically considered yin, were combined with yang foods, such as barley, bean curd, and broccoli.

Gastronomy Point

Wine and Meat The tannins in the wine, which when isolated cause a bitter taste, bind with the proteins in the meat, causing the wine's flavor to soften.

Green Point

Appliances To conserve energy and to reduce your carbon footprint when cooking, you should use large appliances only when preparing large quantities of food. When cooking a small amount of food, it is more energy-efficient to use smaller appliances (e.g., toaster oven, small grill).

Dry heat cooking methods Meat preparation methods that do not include the addition of liquid, such as broiling, grilling, frying, and roasting.

served warm, it is appropriate to balance it with a chilled salad, such as a fruit or vegetable salad. Tender cuts of meat may also be complemented by the crunchy texture of a raw salad. Stew meats are traditionally served in a stew along with cooked vegetables, such as potatoes, carrots, and celery.

In some cultures, it is customary to serve wine with meat-based meals; typically, red meats are expected to be served with a room-temperature red wine. A fruity pinot noir may be used to complement the intense flavor of lamb, or a peppery-flavored shiraz may be paired with a pepper steak. In the end, however, the flavors of wine vary widely, as do personal tastes. The final decision on wine pairing should always rest with the consumer and his or her palate.

Basic Meat Preparation Techniques

Heating and Cooking Methods

The methods used to cook meat depend on the characteristics of the meat. Well-marbled and juicy cuts of meat are best prepared using dry heat methods, whereas lean and less juicy cuts of meat are better prepared using moist heat methods. The type and amount of heat applied ultimately affect the physical changes in the meat and the outcome of the final product. The length of time for which heat is applied also impacts the safety of the food being consumed.

Before meats are cooked, they are typically prepared by removing the outer layers of fat and connective tissue as well as excess water found on the surface of the meat. Although the fat and connective tissue serve to protect the meat while it is raw, they can contribute to poor flavor and texture if left on during cooking. Water on the surface of meat should be removed prior to cooking to minimize the loss of color and nutrients during the heating process.

Dry Heat Methods

Cuts of meat that contain intramuscular fat and moisture are best prepared using **dry heat cooking methods** such as broiling, grilling, frying, and roasting. These techniques use minimal amounts of water-based liquids and rely on the composition of the meat to promote a desirable flavor and texture. As with any cooking method, the application of heat will cause the proteins in meat to become denatured and move closer to each other. As these strands of proteins coalesce, water is expelled from the product, causing shrinkage. In dry heat methods, the water released from the meat will drain away, causing the meat to contain less moisture and to be less juicy. Thus, dry heat methods are typically used on highly marbled pieces of meat that maintain their palatability because of their high fat content.

Broiling

Broiling involves the application of intense, direct, high heat for a short period of time. Broiling is usually done in an oven heated to a temperature of 375–500°F (191–260°C); it is never done at a temperature less than 350°F (177°C). Pieces of meat sliced up to 3 inches thick are placed on a broiling pan specially designed for this cooking technique. A basic broiling pan contains openings that allow the grease and drippings to drain away from the heat source, minimizing the potential for smoke and fire. Meats are cooked with one side facing the heat source for 6 to 14 minutes, then turned over with tongs so that the other side can be exposed for an additional, but shorter, amount of time. The longer the meat is exposed to heat, the more well done the meat will be.

Thick cuts should be placed on racks located in a lower position in the oven. For example, a steak that is 3 inches thick should be placed on a rack that is in the lowest position and farthest away from the oven's heat source. In contrast, a 1-inch thick steak should be placed on a rack that is close to the heat source and is only one or two positions away from the top. The goal of broiling is to heat the center of the meat to the desired doneness while also producing adequate browning on the outside of the meat. These characteristics can be achieved through correct positioning of the broiling pan in the oven and careful monitoring of cooking time.

Pan-Broiling

Pan-broiling is similar to broiling in that it involves the application of high heat to a piece of meat. However, pan-broiling is carried out on the stovetop range using a flat grill, griddle, or heavy pan. Cuts of meats that are prepared via pan-broiling should be no thicker than ½ inch to ensure that they will reach the desired browning and internal texture. Ground beef patties and thinly sliced steaks and lamb chops are commonly prepared using this technique. During the cooking process, drippings, grease, and accumulating liquid should be removed to prevent splattering and to avoid frying the meat in the fluid.

Grilling

Grilling is another dry heat method that is similar to broiling. In grilling, however, heat is applied below the meat as opposed to above it. When the grilling method is used, meats should be less than 3 inches thick. Prior to cooking, the grill must be heated to the desirable temperature, which may take up to 30 minutes. When cooking the meat, the meat can be placed directly on the grilling surface, in a grill pan, or in a griddle.

During the grilling process, excessive exposure of the meat to temperatures above 500°F (260°C) can cause the Maillard reaction to occur. The **Maillard reaction**, named after chemist Louis-Camille Maillard, is a heat-mediated reaction between an amino acid and a reducing sugar; it causes nonenzymatic browning, which commonly occurs during grilling.

Grilling has raised concerns in recent years because the Maillard reaction is known to produce heterocyclic amines, benzopyrenes, and poly-cyclic aromatic hydrocarbons. All of these chemicals have been recognized as potential cancer-causing agents (see **Special Topic 7.3**).²³ Marinating meats before grilling will significantly reduce the formation of these potential carcinogens, particularly the heterocyclic amines.²⁴

Maillard reactions A series of nonenzymatic reactions between reducing sugars and amino groups of amino acids and proteins; it results in a brown color and change in flavor for the food.

Frying

Frying, unlike grilling and broiling, requires the addition of fat or oil to the meat that is being cooked. Fats and oils can transfer heat at much higher temperatures than water. Vegetable oils also have relatively high smoke points, meaning that they will not begin to form acrolein and smoke until they have reached a temperature of 400–500°F (204–260°C). Frying techniques include sautéing, stir-frying, pan frying, and shallow and deep fat frying. All are considered dry heat techniques for cooking meats.

Sautéing is a technique similar to pan-broiling, in that the thinly sliced meat is added to a heavy pan over high heat on a range. When sautéing, however, a small amount of fat—usually in the form of clarified butter or vegetable oil—is also added to the pan. The addition of the fat allows the meat to brown and retain the flavor of the fat.

Stir-frying is carried out over high heat on a stovetop range. With this technique, bite-sized portions of meat are placed in a wok or sloped-edge pan

Special Topic 7.3

Heterocyclic Amines and Grilling Meat

Isabel Smith

Heterocyclic amines (HCAs) are mutagenic agents found in meat products that are cooked at high temperatures. They most often form in meat products that are grilled, baked, or pan fried. When the meat is exposed to a temperature of 300°F (149°C) or higher, chemical changes in the creatine and creatinine proteins present in the muscle tissue may cause formation of HCAs. A person who then eats this meat may be at a greater risk for DNA mutation. The potential for DNA mutation differs from person to person and depends on the presence of certain enzymes. In a process called *bioactivation*, DNA may be mutated by the HCAs; these changes in DNA structure may lead to development of cancer.¹

Studies have found that eating large amounts of HCAs may be specifically associated with breast, prostate, and colorectal cancers.² Although most studies thus far have examined the effects of HCAs in animals, current studies are seeking to identify the results of high HCA consumption in humans.

HCAs are found mostly in beef and chicken, although fish that is cooked at very high temperatures may contain HCAs as well. The National Cancer Institute recommends the following techniques to avoid large amounts of HCAs in meat:¹

1. Avoid exposing meat directly to the flame or to the hot surface, such as grill grates.
2. Use the microwave to precook meat so that it is exposed to the open flame for less time.
3. Turn meat continuously on a hot surface so that HCA formation is reduced.
4. Remove charred portions of the meat and refrain from eating the drippings from meat that has been cooked at very high temperatures.

References

- 1 National Cancer Institute. Chemicals in meat cooked at high temperatures and cancer risk. October 5, 2011. <http://www.cancer.gov/cancertopics/factsheet/Risk/cooked-meats>. Accessed September 18, 2017.
- 2 Norrish A, Ferguson L, Knize M, et al. Heterocyclic amine content of cooked meat and risk of prostate cancer. *J Natl Cancer Inst*. 1999;91(23):2038-2044.

coated in a small amount of oil. As heat is applied to the pan, the meat is constantly stirred to promote thorough and even cooking. In both sautéing and stir-frying, vegetables, seasonings, and sauces may be added to impart additional flavors and textures to the dish.

Like sautéing and stir-frying, pan frying (or shallow frying) takes place in a heavy pan on the range; however, more fat is typically added. Up to ½ inch of oil or fat is added to the pan; as a result, the meats prepared using this technique can be larger and thicker than those used in sautéing or stir-frying. The temperature used in pan frying is lower than the temperature used for sautéing—pan-frying temperatures never exceed 375°F (191°C). Meats prepared using pan frying may be unseasoned and raw, or they may be coated with flour or breading. When raw or cool uncooked meats are added to a hot pan and oil, the temperature of the oil will drastically decline, limiting the oil's ability to cook the meat and causing the oil to infiltrate the meat. The final product will then be greasy and oil-laden. This outcome can be avoided by adding room-temperature or slightly warmed raw meats to the oil. This approach keeps the oil's temperature high, cooks the meat internally, and allows the steam from within the meat to push out and keep the oil from penetrating the meat's surface.

Deep fat frying usually involves submerging food in oil or fat and is done in a large pot over the stovetop or by a separate appliance called a deep fat fryer. Food is usually deep fat fried at temperatures in the 345–375°F (175–191°C) range. At this temperature, the water in food repels the oil and

does not allow for seepage inside. Deep fat frying at too low of a temperature will cause unwanted retention of fat in the food.

Roasting

Roasting is a dry heat cooking method (using indirect heat) commonly used in the preparation of large portions of meat. Typically, a roast will be a minimum of 2 to 3 inches thick and will yield more than four servings of meat per roast. For example, center-cut pork loin, leg of lamb, and veal are commonly prepared using the roasting technique. Roasting is performed in an oven heated to a minimum of 300°F (149°C). Lower temperatures of 300–350°F (149–177°C) will produce uniform and tender, juicy products, whereas higher temperatures of 350–500°F (177–260°C) will produce roasts with a seared crust and a slightly smaller product due to shrinkage. In general, roasts take approximately 18 to 30 minutes per pound to cook, but a meat thermometer should be used to verify that the desired internal temperature has been reached.

When the roasting technique is used, meats are arranged in the center of an open pan and placed in the oven. The open pan allows the drippings and liquid to evaporate during cooking and prevents simmering from occurring. Once the roast has reached the desired internal temperature, it is allowed to stand for an additional 20 to 30 minutes prior to carving to allow redistribution of juices.

Moist Heat Methods

Moist heat cooking methods are the preferred techniques for preparing meats that are lean and that contain more collagen. When moist heat methods are used, the proteins in the meat become denatured, and the tough collagen begins to break down. However, moist heat methods do not reach temperatures as high as those reached in dry heat methods and do not cause browning or excessive fluid loss. The fluid used in moist heating may reach a slight boil, but the cooking environment is slower and more controlled than with the dry heat methods. As a result of these conditions, the lean muscle tissue becomes juicy and tender, making the overall final product more palatable than if a dry heat method were employed. The most commonly utilized moist heat cooking methods include braising, stewing, simmering, pressure cooking, and steaming.

Moist heat cooking methods

Meat preparation methods that include the addition of a liquid (e.g., water), such as braising, stewing, simmering, and steaming.

Braising

Braising often is used on lean cuts of meat such as shoulder of lamb and beef chuck. Braising is most well-known for its use in preparing beef pot roast. Braising is done by placing a large piece of meat in a covered pan, searing the outside, and then adding a set amount of liquid, broth, or stock to the pan. The amount of liquid added should be minimal to prevent the dilution of flavors. Although braising can be carried out on a stovetop range, it is most commonly done in an oven preheated to a temperature in the range of 300–350°F (149–177°C). The meat is allowed to simmer in liquid for several hours. As it simmers, the collagen begins to denature and melt, causing the meat to become more tender and increasing the thickness of the liquid. The moisture from the liquid is also incorporated into the muscle fibers, making the final product more juicy and palatable. Braised meat is considered done when the meat can be easily pulled apart with a fork.

Prior to braising, steps can be taken to ensure that the final product has the desired taste and texture. Because of the presence of liquid, braising does not allow for the Maillard reaction to occur; thus, if a crisp outer consistency is desired, it must be achieved prior to braising. The meat cut may be dusted with seasoned flour and browned on the stovetop range to sear the outside edges of the meat before it is placed in the braising pan. In addition to the

prebraising browning of meat, other desirable flavors can be incorporated into the meat by the addition of seasonings and vegetables to the braising pan. Vegetables, such as potatoes, carrots, onions, and celery, often are sautéed and added to the braising pot to help add flavor and color to the final dish.

Stewing

Although similar to braising, stewing is typically done using more liquid and is carried out for a longer period of time than braising. Stewing is a popular way of preparing cuts of meats that contain a high percentage of collagen and connective tissue because the meat is exposed to the moist, heated conditions for a long period of time. During this time, the collagen will have sufficient time to melt. The proteins within the meat also cook, but they will not become denatured and toughen very quickly. Thus, by the end of the cooking time, the collagen has broken down, the meat is not overcooked, and the final product is palatable. To increase the meat's exposure to heat and moisture, the chef may cut the meat into smaller pieces to increase the overall surface area. The internal temperature of meats that are stewed or braised rarely exceeds 210°F (99°C); to ensure food safety, the product must be kept at this temperature for approximately 25 minutes.

Simmering

Meats prepared by simmering are submerged in liquids kept just below the boiling point of water, usually around 180–200°F (82–93°C). The liquid is first brought to a boil, then its temperature is lowered before the meat is added. As in stewing and braising, the meat never reaches a high internal temperature, so it must be kept in the simmering liquid long enough to fully cook and for the collagen to convert to gelatin. The liquid used to simmer the meat is typically made of a water base; if the chef uses a milk base, the resulting dish may be referred to as “creamed” instead of “simmered.”

Steaming

Steaming—a form of indirect heating—is not used very often when preparing meats. However, some meats that have already been cooked and refrozen may be reheated using this method. Steaming is considered a moist heat method because the meat is placed above a boiling liquid, with the steam created from this boiling liquid then heating the meat. The time needed for the steaming techniques to reheat cold or frozen meats will depend on the size and weight of the meat product.

Nutritional Properties

Nutritional Value of Meats

Meats add a tremendous amount of nutritional value to the typical American diet. Not only are beef, lamb, and pork a significant source of high-quality protein, but they also provide an abundance of vitamins and minerals that are easy to digest and absorb. At the same time, meats are a primary source of saturated fats and cholesterol in the American diet and, therefore, should be eaten in moderation.

Protein

A 3-ounce portion of meat provides roughly 21 grams of protein, although the actual value may be somewhat less in untrimmed cuts of meat. Because this protein originates from animal sources, meat is a source of complete protein, meaning that it contains the essential amino acids that the human

body is unable to synthesize. The effect of excessive animal protein on human health remains unclear,²⁵ although some research has shown that excessive protein intake from animal sources may contribute to the development of diabetes mellitus.²⁶

Fats

Meats are a significant source of dietary fat. In particular, meat is one of the largest sources of saturated fat in the American diet. Chemically speaking, saturated fatty acids are hydrocarbon chains, approximately 12 to 20 carbons in length, bound together by single bonds. Much research has examined the effects of consuming a diet high in saturated fat; to date, the general conclusion has been that such diets are associated with multiple chronic health conditions, including heart disease, hypertension, and hyperlipidemia. The current recommendation put forth by the *2015–2020 Dietary Guidelines for Americans* is to limit saturated fat intake to less than 10% of the overall daily caloric intake, or less than approximately 22 grams of saturated fat per day when following a 2000-calorie diet.²⁷

Several factors influence the amount of dietary fat obtained from meat consumption.²⁸ Lean cuts of meat that are trimmed and have little marbling will contain significantly less fat than untrimmed, well-marbled cuts. Cooking and preparation methods also affect the amount of total and saturated fat found in meats. Meats prepared by grilling and broiling often have less fat; as the meat cooks, the fat liquefies and drains away from the meat. Although this reduces the fat content, it tends to make the meat less tender.

Cholesterol

Meats are a well-known source of dietary cholesterol. Cholesterol is a sterol-based molecule found in animal products; because sterols are fat-based molecules, the cholesterol content of meats usually increases as the saturated fat content increases. For example, a 3-ounce serving of 95% lean ground beef will contain approximately 2.5 grams of saturated fat and 75 mg of cholesterol, whereas a 3-ounce serving of a lamb rib chop will contain 10.8 grams of saturated fat and almost 100 mg of cholesterol.

Previous guidelines and recommendations encouraged consumers to limit their intake of dietary cholesterol so as to reduce the risk of cardiovascular disease and other chronic health conditions; however, emerging research has caused scientists to question the relationship between dietary cholesterol intake and disease risk. Given this uncertainty, the American Heart Association and the *2015–2020 Dietary Guidelines for Americans* do not put limits on the amount of dietary cholesterol an individual should consume, but they do continue to recommend limiting intake of saturated fat.

Carbohydrates

Most of the carbohydrate found in the muscle tissue of animals is converted to lactic acid shortly after slaughter. As a result, meat does not provide a significant amount of carbohydrate to human dietary intake. Some prepared meats, however, may be battered and fried, and the batter (e.g., cornmeal, flour) will provide a small amount of carbohydrate.

Vitamins and Minerals

Meats contribute a number of vitamins and minerals to the human diet. Because of the biological similarities between animals and humans, many nutrients found in animal-based products, such as meat, are readily digested and absorbed by the human body.

Iron

The iron content of meat products depends on the type of meat as well as the fat and muscle content of the cut. In general, a 3-ounce portion of beef, lamb, or pork contains 4–7 mg of iron, which is significant given that a healthy adult typically needs 8–18 mg/day. Iron found in meat products is known as heme iron. This type of iron is considered to be of high biological value because it is readily absorbed by cells in the intestine and does not have to be converted before it can be utilized in the human body.

Zinc

Zinc is another mineral found in high concentrations in red meats. In the human body, zinc helps to catalyze enzyme-dependent reactions and plays an important role in the maintenance of body proteins and cellular membranes. The average 3-ounce serving of beef contains 6 mg of zinc; an equivalent serving of pork contains 2.2 mg of zinc. The Recommended Dietary Allowance (RDA) for adult males is 11 mg/day; the RDA for adult females is 8 mg/day. Individuals consuming red meat usually meet these recommended amounts without needing additional supplementation.

Phosphorus and Copper

Red meats are also high in minerals such as phosphorus and copper. Phosphorus, which is found in high concentrations in the human body, helps to maintain bones and teeth. Meats are an excellent source of phosphorus, with a 3-ounce serving of beef containing 90–400 mg of phosphorus (the RDA for phosphorus for a healthy adult is 700 mg/day).

Copper, an essential trace element, plays an active role in human metabolism and the formation of connective tissue. Although adults need only 900 µg of copper per day, 1 ounce of beef liver contains more than 4000 µg of this element.

B-Complex Vitamins

The B-complex vitamins (thiamin, riboflavin, niacin, B₆, folate, and B₁₂) are the most abundant vitamins found in red meats. Vitamin B₁₂, a vitamin essential for brain function and blood formation, is found almost exclusively in animal-based products. A 3-ounce portion of top sirloin beef contains almost 100% of the recommended daily intake of vitamin B₁₂. Because this vitamin is not found in many plant-based foods, vegetarians and vegans sometimes get B₁₂ injections to avoid developing a deficiency.

Nutrient Retention with Use of Dry Heat Cooking Methods

Cooking with dry heat methods tends to preserve the nutritional value of meats better than cooking with moist heat methods because there is no addition of liquid, which can dissolve water-soluble vitamins. Nonetheless, some of the nutritional content of meats will be lost during any type of cooking simply due to heat exposure and the loss from drippings. **Table 7.3** describes the percentage of various nutrients retained from the raw product once the meat has been prepared.

In meats that are broiled, approximately 80–100% of the iron and 100% of the zinc is retained. Approximately 85–90% of the phosphorus is retained, and 75–100% of the copper is retained (ground broiled lamb retains only 75% of the copper from the raw product). The B-complex vitamins are not as well retained during broiling. As little as 60% of thiamin and vitamin B₆

TABLE 7.3
Percentage of Select Nutrients Retained (Nutrient Retention Factor) After Use of Specified Preparation Methods of Meats

Type of Meat	Iron (%)	Zinc (%)	Thiamine (%)	Riboflavin (%)	Niacin (%)	Vitamin B ₆ (%)	Folate (%)	Vitamin B ₁₂ (%)
Beef								
Roasted	100	100	55	95	75	50	95	70
Broiled, cut	95	100	70	90	80	60	85	80
Broiled, ground	95	100	80	95	90	60	85	80
Fried, without coating	95	100	70	90	80	60	85	80
Fried, with coating	95	100	70	90	80	60	85	80
Veal								
Broiled	90	100	65	90	80	65	75	80
Fried, without coating	90	100	65	75	85	45	85	95
Fried, with coating	90	100	65	90	80	65	75	80
Roasted	85	100	60	90	80	50	85	85
Lamb								
Broiled	95	100	60	90	80	65	70	80
Ground, broiled	95	100	70	80	85	75	70	75
Roasted	100	100	60	90	80	75	85	75
Pork								
Fresh, broiled	80	100	70	100	80	65	85	90
Fresh, fried without coating	80	100	70	100	80	65	85	90
Fresh, fried with coating	80	10	70	100	80	65	85	90
Fresh, roasted	100	100	60	95	85	85	95	80

Modified from U.S. Department of Agriculture, Table of nutrient retention factors, Release 6, 2007.

is retained by broiled meat, and only 75–90% of vitamin B₁₂ is retained. Many broiled meats are ground prior to cooking, such as ground beef; however, this type of physical change does not contribute to a substantial loss of nutrients.

Frying meats also causes some nutrient loss, but in veal it appears that the amount lost often depends on whether the meat was coated prior to frying. For example, uncoated fried veal retains 75% of its riboflavin and 45% of its vitamin B₆, whereas coated fried veal retains 90% of its riboflavin and 65% of its vitamin B₆. Pork, beef, and lamb appear to have similar nutrient retention values regardless of coating. Although most coated meats do retain most of their nutritional value, they also contain more calories and carbohydrate due to the coating.

Roasted meats retain 100% of their iron and zinc, with the exception of roasted veal, which retains only 85% of its iron. Only 55–60% of the thiamin is retained in roasted meats, whereas as much as 95% of the riboflavin and 90% of the niacin is retained. Roughly half of the vitamin B₆ is retained in roasted beef and veal, whereas 75% is retained in roasted lamb and 85% is retained in roasted pork. Approximately 70–85% of vitamin B₁₂ is retained in roasted meats, with the highest retention being in roasted veal.

Nutrient Retention with Use of Moist Heat Cooking Methods

Nutrient retention when moist heat methods are used to cook meats is highly dependent on whether the drippings and liquid are retained. Many of the

vitamins and minerals present in these meats will be forced out and into the drippings as a result of the moist heat cooking method. After cooking, if the liquid is consumed, many of the nutrients are retained; however, if the liquid is discarded after cooking, then more than 50% of some nutrients may be lost due to their water solubility.

Regardless of whether the drippings are consumed, roughly all of the iron and zinc are retained from beef, veal, lamb, and pork when prepared using any of the moist heat methods. Only 5% of the iron content is lost when the drippings from veal are not consumed. For most of the B-complex vitamins, the percentage lost is approximately 15% greater in meat products without the drippings as compared to products with the drippings. For example, simmered roast beef that is consumed along with its drippings retains 60% of the thiamin from the original product. If the same product is consumed without its drippings, however, only 45% of the thiamin is retained. The largest percent difference is seen in niacin retention: Consumption of the drippings from braised roast beef can result in a retention factor of 90%, whereas avoiding the drippings results in a retention factor of only 55%.

Going Green with Meats

Impact of Meat Production on the Environment

Because meats are produced from animals high on the food chain and therefore have a large carbon footprint, the consumption of meat products has received scrutiny from environmental groups and organizations. Agricultural operations, including the breeding and raising of cattle and other animals, have caused major problems with water and land contamination in the United States. It is estimated that 59% of rivers and 31% of lakes, ponds, and reservoirs have been affected by and polluted due to such operations.²⁹ Odorous air emissions from animal feeding operations contain more than 330 compounds, including ammonia, hydrogen sulfate, methane, and carbon dioxide; animal manure; and organic waste. These compounds can pollute the air, and the ammonia can be deposited in surface waters, causing eutrophication (i.e., the depletion of oxygen and quick growth of plants and algae in water). Animal manure can pollute land and water surrounding animal feed lots with contaminants such as nitrogen, nitrates, phosphorus, antibiotics, pesticides, and hormones. Nitrogen from animal manure can be found in forms such as ammonia or organic nitrogen, neither of which can be used by plants; instead, they can be readily utilized only via microbial processes.

Animals produce gaseous pollutants such as nitrous oxide and the greenhouse gases carbon dioxide and **methane**. Methane has been estimated to have an environmental impact roughly 15 times that of carbon dioxide, and nearly one-third of all methane produced comes from animals and agriculture operations.³⁰ In 2014, enteric fermentation (digestion of carbohydrate, which results in the release of methane gas) and manure management were responsible for 22% and 8%, respectively, of all methane emissions from human activity.³¹

Because society is more concerned than ever with environmental health issues, government departments such as the Environmental Protection Agency (EPA) have developed recommendations and standards to minimize the impact that agriculture has on the environment.³² As one example, the EPA recommends containing cattle and keeping them from having direct access to surface waters. This federal agency also recommends using concrete ditches to control wastewater runoff and to drain it to a safe holding area. As a regulatory

Methane Greenhouse gas produced by livestock.

measure, the EPA requires farming operations with more than 300 cattle or veal to comply with standards set forth in the Concentrated Animal Feeding Operations Clean Water Act requirements. According to these requirements, animal feeding operations must demonstrate environmentally protective nutrient management systems before being granted the appropriate permits to start operations.

Changing the Environmental Impact of Meats

Meat production requires numerous steps, from breeding and slaughtering to transport and cooking, and each one affords an opportunity for producers and consumers to make wise environmental decisions. Ideally, producers should contain the animals in a large area so the animals' gases (e.g., methane), manure, and other emissions do not build up and become concentrated in the soil and water. Likewise, ensuring that the animals do not have direct access to surface water will prevent contamination of local waters.

The type of feed on which an animal is raised provides another opportunity for greener options. Corn-based feeds require a large input of energy due to the fertilizer and irrigation systems used to produce the corn. In addition, the transportation of the corn to the feedlot burns fossil fuels and emits pollutants into the air. For these reasons, grass-fed cattle are considered to be more environmentally friendly. Cattle can also be fed with feeds rich in urea; such feeds may improve the animal's digestion and, in turn, decrease fermentation and methane emissions by 25–75%.³³

Several other aspects of livestock maintenance contribute to greenhouse gas emissions. The clearing of trees, grass, and other natural structures during the building of farm and livestock operation facilities contributes greatly to greenhouse gas emissions and the deterioration of the environment. As a result, many farming operations have attempted to minimize the clearing of land prior to building such operations. In addition, the combustion of fossil fuels to generate energy contributes to agricultural gas emissions. Although only small amounts of fossil fuels may be burned on the actual farmland, fossil fuels are heavily utilized in the transport of livestock to final feedlots and slaughterhouses. Thus, many operations have “gone green” by limiting the frequency and distance of transportation of their livestock.

Finally, because the producing, slaughtering, and processing of animal meats is so energy intensive, many environmental organizations urge consumers to simply cut back on their overall meat intake. According to the National Resources Defense Council, if every American reduced his or her weekly intake of beef by $\frac{1}{4}$ pound, greenhouse gas emissions would decrease by the same magnitude as taking 6 million cars off the highway.³⁴ Reducing the consumption of processed meats (i.e., sausage, bacon, luncheon meats) also is considered a green decision because of the large amount of energy and resources it takes to preserve, process, and package these products.

Food Safety and Foodborne Illness

Raw meats are considered to be potentially hazardous foods, so they must be handled cautiously in any food preparation environment. Foodborne illness is caused by dangerous pathogens that can multiply quickly in environmental conditions conducive to their growth. Like many foods, meat provides the ideal environment for bacterial growth because it is not very acidic and contains a substantial amount of protein and moisture. To reduce the risk of foodborne illness, meats should be cooked until the innermost portion reaches a safe temperature (**Table 7.4**).

Green Point

50,000 Hogs The waste generated from 100 animal feeding operations containing at least 50,000 hogs is approximately equal to the same amount of waste generated by a city with a population of 150,000 individuals.

TABLE 7.4
Required Internal Cooking Temperatures and Holding Times for Meats for Food Safety Purposes

Product	Type	Minimum Internal Temperature and Rest Time
Beef, pork, lamb, veal	Ground	160°F (71°C)
	Steak, chops, and roasts	145°F (63°C) and allow to rest for at least 3 minutes
Chicken and turkey	Breasts Ground, stuffing, and casseroles Whole bird, legs, thighs, and wings	165°F (74°C)
Eggs	Any type	160°F (71°C)
Fish and shellfish	Any type	145°F (63°C)
Leftovers	Any type	165°F (74°C)
Ham	Fresh or smoked (uncooked)	145°F (63°C) and allow to rest for at least 3 minutes
	Fully cooked ham (to reheat)	Reheat cooked hams packaged in USDA-inspected plants to 140°F (60°C) and all others to 165°F (74°C)

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Fresh and cured meats, meat substitutes, and other animal by-products can harbor a variety of foodborne pathogens. **Special Topic 7.4** provides information on *E. coli* O157:H7, the bacterial cause of an extremely common foodborne illness associated with meats. *Clostridium botulinum* is another bacterium that can be fatal when ingested; however, the addition of nitrites to preserved meats limits this bacterium’s ability to survive in such foods. *Trichinella spiralis*, commonly referred to as “pork worm,” is a foodborne pathogen often found in undercooked or raw pork products.

Special Topic 7.4

E. coli O157:H7

Courtney Winston Paolicelli, DrPH, RDN, LD, CDE

Escherichia coli is a bacterium that commonly inhabits the intestinal tract of livestock, including cattle. Because these bacteria are found in animal guts, they can be easily passed on to humans through animal products that have been contaminated with fecal matter. One of the most fatal *E. coli* strains, O157:H7, is estimated to kill more than 60 people each year¹ and to cause more than \$1 billion annually in damages.² Because of the high risk associated with this strain, cattle producers and food inspection officers closely monitor the processing and packaging of all meat products to minimize potential *E. coli* contamination.

Meats and other food products may become contaminated with *E. coli* through several mechanisms. Ground beef—a common source of *E. coli*-related foodborne illness outbreaks—can become tainted with these deadly bacteria if portions of the cattle intestine are accidentally integrated into the ground product. In addition, cattle “shed” *E. coli* when they defecate, so their manure is often laden with these organisms. As a result, anything coming in contact with the manure (e.g., rainwater, plants, other animals, humans) can become contaminated. It is via this process that drinking and irrigation water may easily become contaminated.

Whereas animals that harbor *E. coli* show fairly mild symptoms, such as loose stools, humans have much more severe reactions, even when infected by as few as 10 individual *E. coli* organisms. Hemorrhagic colitis—a disease characterized by bloody diarrhea accompanied by severe abdominal cramps and a high fever—is the common result of an *E. coli* infection. This condition should

immediately be addressed by a medical doctor; without physician care, the infection can become fatal. All reports of *E. coli* and hemorrhagic colitis should be reported to the local public health department so investigators can identify the source of the infection and remove any other contaminated products from the market.³

To reduce the risk of foodborne illness from *E. coli* contamination, producers and consumers are advised to practice proper hand hygiene and to handle and prepare foods with extreme caution. Meat packing and processing plants are regularly and vigilantly monitored by state and federal inspectors—these inspectors ensure that meat products are not coming into contact with manure or other cattle by-products that may harbor *E. coli*. When purchasing meat products, consumers should buy only products that are tightly sealed in appropriate packaging and are stored at the correct temperatures (e.g., frozen meats should be frozen solid, not slightly thawed). Consumers are also urged to fully cook all animal products, especially ground beef. Furthermore, because fruits and vegetables can become tainted with *E. coli*-containing irrigation water, consumers should prevent infection by thoroughly washing and rinsing these items.

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- 3 U.S. Department of Agriculture. Food safety for older adults. February 9, 2017. https://www.fda.gov/food/resourcesforyou/consumers/ucm312705.htm#Food_safe. Accessed February 12, 2017.

To reduce the risk of foodborne illness, consumers should follow these guidelines when preparing meats:

- Use separate cutting boards for raw meats. Avoid cross-contamination by never placing raw meats on the same surface as raw poultry or ready-to-eat foods such as fruits, vegetables, or starches.
- Thoroughly wash and disinfect utensils, knives, and food preparation equipment after use. Never use cutlery for both raw meats and ready-to-eat foods.
- Do not thaw raw meat by allowing it to sit in the “danger zone”—temperatures between 41°F and 135°F (5–57°C). If a meat appears to be spoiled or damaged, discard it immediately.
- Only purchase meats that have been inspected by the USDA.

Green Point

Eating Local Meat Eating local livestock that are raised within 250 miles and do not have to be transported over long distances definitely reduces a person's carbon footprint.

Meat Regulations and Quality

Meat Inspection

The USDA mandates that meats from beef, veal, pork, and lamb go through **inspection** prior to being sold. The federal-level Food Safety and Inspection Service (FSIS) maintains responsibility for inspecting all meats brought into the United States from foreign countries and all meats that are sold through interstate commerce within the United States. Meats that are both produced and sold within one state may be inspected by that state's inspection program, but such state-level programs are closely and regularly monitored by FSIS. In accordance with the 1967 Wholesome Meat Act, state-level inspection programs must apply the same or more stringent guidelines than the federal program. Although the FSIS and state agencies are primarily responsible for meat inspections, they also work closely with the Food and Drug Administration, the U.S. Department of Health and Human Services, and the Environmental Protection Agency. All funds for meat inspection, both on the federal and state levels, are secured from taxpayer dollars.

Inspection A federally mandated process whereby trained officials inspect meat processing plants to ensure food safety.

The primary purpose of meat inspection is to ensure that meat being sold on the market is “wholesome,” free of disease and contamination, and safe for human consumption. For example, one of the goals of meat inspection is to prevent the spread of bovine spongiform encephalopathy (BSE), or “mad cow disease,” described in **Special Topic 7.5**.

Special Topic 7.5

Bovine Spongiform Encephalopathy (“Mad Cow Disease”)

Jennifer Stallings

In 1986, a farmer in Great Britain noticed peculiar behaviors in one of the cows in his cattle herd before its eventual death. Other animals on the farm began to show similar nervous and aggressive behaviors coupled with difficulty standing, decreased body weight, and decreased milk production. A laboratory examination of the brain of a deceased cow showed hole formations, which caused a spongelike appearance. Researchers recognized these cases as involving a disease called bovine spongiform encephalopathy (BSE), commonly known as “mad cow disease.”¹ Scientists at the Central Veterinary Laboratory in Weybridge, England, identified BSE in many more of the symptomatic cattle and began to search for the cause. A common factor between all of the infected animals was their feed—a mixture made from the carcasses of dead animals that had died due to BSE. Once this practice was halted, the incidence of BSE decreased.²

In 1982, Stanley B. Prusiner, an American neurologist, had discovered the cause of BSE—protein particles without DNA or RNA, called prions. Once inside the host, prions traverse the spinal cord, entering the brain. There, the prions cause a chain reaction in which normal proteins begin to stick together, forming plaques and eventually holes in the central nervous system.³

Prion diseases such as BSE belong to the family of transmissible spongiform encephalopathies (TSEs). According to the Centers for Disease Control and Prevention, TSEs are progressive neurodegenerative disorders affecting both humans and animals. Human consumption of contaminated products causes variant Creutzfeldt-Jakob Disease (vCJD), which is characterized by memory loss, headaches, and changes in gait. Clinical symptoms arise an average of 5 years after infection. As the brain damage progresses, the patient’s cognitive ability and motor skills deteriorate, eventually leading to death. Prions are resistant to viral inactivation techniques, making TSEs resistant to treatment. Currently, a cure for TSEs does not exist.²

Following the 2003 discovery in Washington of the first BSE-infected cow in the United States, the USDA has focused on the effectiveness of current policies in dealing with this threat. Because the infected dairy cow had been imported from Canada, the International Review Team (IRT) addressing the issue recommended a surveillance program for BSE in North America. Two additional cases of BSE were discovered in the United States a year later: a Texas born-and-raised beef cow in November 2004 and an Alabama cow in February 2006.⁴ A statement from the USDA following a recall of beef after the first discovery stated that some of the contaminated meat may have been consumed but that the highest-risk tissues of the cow had not entered the food supply. Although the first discovery of BSE in the United States involved a cow from Canada, Japan, Mexico, South Korea, and some other countries banned imports of U.S. beef and cattle.³

Since 1989, the USDA’s Animal Plant Health Inspection Service (APHIS) and the U.S. Department of Health and Human Services have implemented various safeguards and restrictions to prevent the spread of BSE in the United States.⁵ First, an import control was created to prevent entry into the United States of ruminant animals and their meat products from countries where BSE had been found. Then APHIS began testing cattle that were considered higher risk in that they displayed suspicious neurologic symptoms, were not ambulatory, or had died before slaughter. Use of organs that could accumulate the BSE-causing prions—such as the spinal cord, brain, or nerve tissues—was banned from the meat supply through meat plant regulations developed by the USDA’s Food Safety and Inspection Service. Along with this ban, the production of meat from nonambulatory cattle was prohibited. The Federal Drug Administration prohibited the presence of mammalian proteins in animal feed in 1997. Seven years later, poultry and plate waste as well as blood from cattle were also banned in cattle feed.⁵

Other measures put into place by the FSIS include an inspection of cattle for disease signs and symptoms. Suspect cattle undergo examination by an FSIS veterinarian for determination as to whether the animal is safe to enter the human food supply. Removal techniques have been developed that separate parts of the animal presenting increased risk, such as the brain, spinal cord, and eyes. FSIS maintains strict testing procedures and requires slaughter and processing establishments to develop similar procedures.⁵

Cattle production represents the largest sector of U.S. agriculture and accounts for one-fifth of total U.S. farm sales. As of 2011, an estimated 2.8 billion pounds of beef was exported to other countries on an annual basis.⁵ Adequate food safety measures should allow for continued import and export of meat products and prevent the consumption of TSE-contaminated food, by animals and humans both. These safeguards represent scientific and policy practices by the U.S. government to protect the food supply.⁶

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Because raw meats can potentially be a major source of foodborne illness, inspectors do more than just visual inspections. For example, they test for potential biological and chemical hazards (**Figure 7.11**), and they critically investigate the meat packing plant's Hazard Analysis and Critical Control Point (HACCP) plan. The HACCP plan is basically a seven-step management plan put together by the manufacturers of food products to ensure that their food products do not become contaminated with bacteria, viruses, or other foreign materials.³⁵ The seven HACCP steps are outlined in **Table 7.5**.

Part of the meat inspection process involves making sure that all meats are correctly labeled and packaged. One of the important labels that must be placed on all raw, uncooked, or not fully cooked meat is the "Safe Food Handling" label. This label conveys safe food handling information directly to

TABLE 7.5 The Seven-Step Process of a Hazard Analysis and Critical Control Point Plan	
Principle	Action
1	Conduct a hazard analysis.
2	Determine the critical control points.
3	Establish critical limits.
4	Establish monitoring procedures.
5	Establish corrective actions.
6	Establish verification procedures.
7	Establish record-keeping and documentation procedures.

Reproduced from the U.S. Food and Drug Administration. Hazard Analysis and Critical Control Point Principles and Application Guidelines, 1997.



FIGURE 7.11 As part of the inspection process, a microbiologist gathers carcass samples for microbial analysis.

Courtesy of the USDA Agricultural Research Service. Photo by Keith Weller.

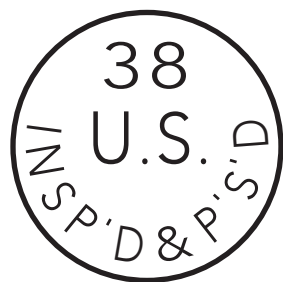


FIGURE 7.13 All raw meats must be inspected by the USDA and stamped with the USDA inspection mark.

Reproduced from U.S. Department of Agriculture, Food Safety and Inspection Service. Inspection and grading of meat and poultry: What are the differences?



FIGURE 7.14 The inspection mark for processed meats, shown here, differs from the inspection mark for raw meats.

Reproduced from U.S. Department of Agriculture, Food Safety and Inspection Service. Inspection and grading of meat and poultry: What are the differences?

Nutrition Facts	
Servings per container varied raw, as packaged.	
Serving size	4 oz (112g)
Amount per serving	
Calories	150
% Daily Value*	
Total Fat 6g	9%
Saturated Fat 2.5g	13%
Trans Fat 0g	
Cholesterol 70mg	23%
Sodium 75g	3%
Total Carbohydrate 0g	0%
Dietary Fiber 0g	0%
Total Sugars 0g	
Includes 0g Added Sugars	0%
Protein 24g	
Vitamin D 3mcg	1%
Calcium 14mg	1%
Iron 1.8mg	15%
Potassium 247mg	5%

* The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

(a)

Nutrition Facts	
Servings per container varied raw, as packaged.	
Serving size	4 oz (112g)
Amount per serving	
Calories	210
% Daily Value*	
Total Fat 12g	19%
Saturated Fat 3.5g	18%
Trans Fat 0g	
Cholesterol 75mg	25%
Sodium 75g	3%
Total Carbohydrate 0g	0%
Dietary Fiber 0g	0%
Total Sugars 0g	
Includes 0g Added Sugars	0%
Protein 23g	
Vitamin D 3mcg	1%
Calcium 14mg	1%
Iron 0.8mg	6%
Potassium 247mg	5%

* The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

(b)

FIGURE 7.12 The Nutrition Facts label seen on most processed foods must now be included on all packages of raw ground beef, turkey, and chicken. **A.** Beef, ground, 95% lean/5% fat, raw. **B.** Chicken, ground 89% lean/11% fat, raw.

Reproduced from U.S. Department of Agriculture, Food Safety and Inspection Service. Examples of Nutrition Facts Panels for Ground Products.

purchasers of the product, and it reminds them to fully cook the meat prior to consuming it (Figure 7.12).

Once the meat has met all of the inspection requirements, it will be stamped with a round, purple mark. There is one inspection mark for fresh meat and another inspection mark for processed meat, and both of these marks are slightly different than the inspection mark used for poultry (Figure 7.13 and Figure 7.14). The mark is placed directly on the carcass and all other major cuts of that particular meat. The purple dye used for the inspection mark is made from food-grade vegetable dye and does not taint or contaminate the meat.

Other meats, such as elk, buffalo, rabbit, and deer, are not subject to mandatory inspection; however, the U.S. Secretary of Agriculture still reserves the right to take necessary precautions to ensure that these meats are safe for consumption. Plants that process meats other than beef, pork, and lamb and that request voluntary inspection are inspected by a trained FSIS inspector who is privy to that specific meat’s inspection requirements. Funding for these voluntary inspections is secured from the plant being inspected, not from taxpayer dollars.

Meat Grading

Whereas meat inspection is mandatory, meat grading is not. Grading is done solely at the discretion of meat producers and processors. Because of this, they must pay for this service using their own funds. Grading is a process by which the quality of meat is assessed; all meat grading is done by the

Grading A voluntary process in which meat products are rated for their quality.

USDA's Agricultural Marketing Service (AMS). AMS uses federal standards of quality to assess meat products and gives a corresponding grade based on its findings. Part of the grading process involves assessing the meat's tenderness, juiciness, and flavor characteristics. Poultry is graded similarly; however, criteria for poultry are slightly different than those for meat. Grades for meat differ depending on the type of meat.

Beef

After being assessed as an entire carcass, beef receives two grades: a quality grade and a yield grade. The quality grade indicates palatability traits (i.e., marbling, age, pigmentation), whereas the yield grade indicates the amount of usable lean meat.

The top-quality grade of beef is Prime. Meats with this grade are typically from young cattle and are generally well marbled. The next grade, Choice, also is considered high quality, but such meats tend to have less marbling and may be less tender. They are still appropriate for dry heat cooking methods, but some cuts may have better palatability if braised. Select grade beef is less marbled than Prime and Choice meats and often lacks the juiciness and flavor associated with higher grades. Standard or Commercial grades of beef follow behind Select. Finally, Utility, Cutter, and Canner grades of beef are the lowest grades given by the AMS. These low grades are often given to meats that are used only for ground beef or other processed meat-based products. **Figure 7.15** shows the stamps used to identify different quality grades of beef.

Yield grades of beef range from 1 to 5. Beef carcasses that receive a yield grade of 1 will have a high ratio of lean meat to fat, whereas carcasses with a yield grade of 5 will have only a small amount of lean meat relative the rest of the carcass.

Veal

From highest to lowest quality, the grades used for veal are Prime, Choice, Good, Standard, and Utility. As with beef, the Prime and Choice grades of veal indicate a highly palatable product. These two grades of veal will be juicy and flavorful. Veal with a Prime or Choice grade will also have a fairly firm texture and will be light grayish-pink to light pink in color. Lower grades of veal are not as commonly marketed.

Lamb

Similar to veal, lamb grades include Prime, Choice, Good, Utility, and Cull. Prime and Choice are the two grades most often seen in restaurants and stores because the lower grades have poor palatability (the lower grades usually come from older sheep). Prime grade lamb is highly marbled, which increases its juiciness, tenderness, and flavor. Choice grade lamb is not quite as tender as prime grade but can still be cooked using dry heat methods if an appropriate cut (i.e., chops, roasts, leg) is used. Other choice cuts (i.e., breast, neck, shank) should be prepared by braising. The overall nutritional content of lamb cuts remains similar across all five grades.

The quality of lamb meat also can be affected by the aging process. After slaughtering, lamb meat may undergo an aging process as a means to bolster the meat's flavor and texture. Lamb ribs and loins are the only cuts of lamb that are usually aged. This process must be performed under very specific temperature and humidity requirements, so it is not a process that should be attempted in a consumer's home or kitchen. The overall aging process can take from 10 days to 6 weeks depending on the desired outcome; most aged lamb then is sold to fine dining establishments.



FIGURE 7.15 Producers can voluntarily agree to have the quality of their meat product graded by the USDA. These seals indicate the quality of the meat. Prime, Choice, and Select cuts are acceptable for human consumption.

Reproduced from U.S. Department of Agriculture, Food Safety and Inspection Service. Inspection and grading of meat and poultry: What are the differences?

Special Topic 7.6

Porcine Epidemic Diarrhea Virus

Courtney Winston Paolicelli, DrPH, RDN, LD, CDE

In May 2013, the USDA's National Veterinary Services Laboratory confirmed the first case of porcine epidemic diarrhea virus (PEDv) in the United States. PEDv is a coronavirus that affects the gastrointestinal tract of swine, causing severe diarrhea and dehydration.¹ In young piglets, PEDv has an extremely high (80–100%) morbidity and mortality rate,² whereas only a small percentage (1–3%) of adult pigs die from the virus.³ While PEDv cannot be transmitted to humans and is not considered grounds for discarding products from infected animals, it is highly contagious among swine, in which it is transmitted by a fecal–oral route.

PEDv was first described in the United Kingdom in 1971.⁴ Because many of the symptoms associated with PEDv were similar to those found in swine with porcine transmissible gastroenteritis (TEG), scientists did not determine that PEDv was a separate virus until six years later. Between 1977 and 2013, PEDv was also discovered in swine from several other European and Asian countries, including China, the Czech Republic, Germany, Hungary, Italy, Japan, Korea, the Philippines, Spain, and Thailand.^{5,6}

In 2013, PEDv was first discovered in swine in Iowa, and then rapidly spread to at least 27 other states.⁷ The increasing number of cases triggered the USDA's Animal and Plant Health Inspection Service (APHIS) to issue a Federal Order on June 4, 2014. This Order required that all new cases of PEDv be reported to USDA or to state animal health officials, and it required that operations reporting these cases implement a comprehensive management plan under the direction of a veterinarian.⁸ In addition to the Federal Order, APHIS made available \$26.2 million in funding to combat PEDv and similar viruses.

Many pork producers experienced difficulty when PEDv arrived in the United States. The average litter rate, or the number of piglets produced per litter, for the U.S. hog industry dropped substantially in late 2013 and early 2014⁹ when the virus was spreading quickly, indicating that not as many piglets were being born. As a result, the cost of pork rose approximately 13% compared to the cost in the previous year.¹⁰ Fortunately, a PEDv vaccine was made available in mid-2014, and by the following year, litter rates had rebounded to pre-2013 rates.

The outbreak of PEDv in the United States is an excellent example of how quickly and significantly meat production can be impacted by animal disease, even when the disease is known to exist in animals in other countries. Fortunately, swift action on the part of U.S. public health officials, federal policy makers, and scientists limited the impact of the disease on U.S. pork food production.

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Pork

Unlike beef, veal, and lamb, pork is not eligible for grading by the AMS because swine are typically raised and bred to produce uniform and tender meat. Although there is little variation in pork, appearance is an appropriate indicator of the quality of meat. Palatable cuts of pork should be covered in only a small amount of fat and should be grayish pink in color. A firm texture with small amounts of marbling also is desirable because this indicates tenderness.

Chapter Review

Red meat plays a significant role in the culture, diet, and health of individuals around the world. Structurally, meat is composed of water, protein, fat, and connective tissue. Because of its chemical composition, meat makes a significant contribution to the overall nutritional status of individuals who consume it. When preparing meat, consumers may use dry or moist heat cooking methods. Dry heat cooking methods are more appropriate for well-marbled, tender cuts of meat, whereas moist heat cooking methods are more appropriate for lean and tough cuts of meat. Meat can be preserved through processes such as curing, and it can also be frozen for extended storage.

The meat industry has received criticism in recent years for its sizable carbon footprint. A plethora of resources (e.g., fossil fuels, water) are required for the production of livestock feed, and even more resources are utilized in the maintenance of livestock ranges, farms, slaughterhouses, and processing plants.

Although meat producers have the option of having their products graded for quality, all meat processing and production facilities must be inspected by the federal government to ensure that the conditions under which these foods are produced are safe and sanitary.

Case Study

Reducing Meat Producers' Carbon Footprints

Meat producers often face many difficulties when it comes to reducing their carbon footprints, partially because of the costs associated with doing so. One Midwest U.S. meat producer, however, has made it his goal to modify his meat production processes and facilities so as to produce and market a “greener” meat product. Currently, the meat producer’s primary product is beef, but he is willing to modify his types of livestock as long as he can keep his operation profitable.

Questions

1. Discuss steps this producer could consider taking to reduce the carbon emissions associated with his agricultural operations.
2. Consider the financial impacts these changes may have on the producer’s budget. How might he reclaim some of the costs associated with the changes?



Learning Portfolio

Key Terms

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Study Points

1. The most commonly consumed meat products in the United States come from cattle (young cattle are sold as veal), sheep younger than 1 year of age (sold as lamb), and domesticated hogs (sold as pork).
2. Beef, lamb, and pork are commonly referred to as red meat because they contain myoglobin pigment, which turns to oxymyoglobin when exposed to oxygen, giving the meat a red coloration.
3. Approximately 6 to 24 hours after an animal is slaughtered, the carcass enters the state of rigor mortis. During this time, the meat maintains a low pH because of the lactic acid in the muscle tissue. If an animal is stressed or exercised immediately prior to slaughter, the meat will not maintain a low pH during rigor mortis, and the animal's muscle tissue will not be as palatable or desirable to the consumer.
4. Many different methods can be used to prepare meats, but the most important consideration is the meat's tenderness. If a meat is tender and well marbled, it can usually be prepared using a dry heat method, such as roasting, broiling, or baking. If a meat is not tender and has little fat, it is best prepared using a moist heat method, such as braising, stewing, or simmering.
5. Meats can be preserved through the process of curing. This process requires the addition of sodium nitrite, which prevents the growth of *Clostridium botulinum* and gives the meat product a longer shelf life.
6. Meat makes a substantial contribution to the overall human diet. Meats are an excellent source of complete protein, and they are also rich in minerals (iron, zinc, phosphorus, and copper) as well as vitamins (thiamin, riboflavin, niacin, B₆, folate, and B₁₂). While most of the proteins and minerals are retained during cooking, many of the water-soluble vitamins are lost.
7. In recent years, meat producers have taken steps to make their processing and production steps "greener." Many producers raise grass-fed animals instead of grain-fed animals, reducing the amount of fossil fuel required to produce the feed. Other producers allow their animals to roam on large ranges so that the animal by-products do not build up in the nearby soil and waters. Because of the amount of resources it takes to raise, transport, slaughter, and prepare animal products, some individuals limit their meat intake and elect to consume fewer meat-based meals and more vegetarian meals (e.g., meals containing textured soy proteins and other soy-based foods).
8. Meats should be prepared and consumed under sanitary conditions. To reduce the risk of foodborne illness, food handlers must take precautions such as cooking meat to a safe internal temperature, separating raw meats from uncooked foods, and purchasing only meats that have been inspected by the FSIS.
9. *Escherichia coli*, a group of bacteria that commonly inhabit the intestinal tract of livestock animals, is a common source of foodborne illness. To prevent bacterial infection, consumers need to prepare foods appropriately and avoid cross-contamination.
10. The USDA monitors the integrity of the U.S. meat processing industry by requiring the Food Safety and Inspection Service to inspect all U.S. meat-processing facilities.
11. Meat manufacturers may elect to have their meat products (beef, veal, and lamb only) graded by USDA's Agricultural and Marketing Service. Grading evaluates the quality of meat, whereas inspection evaluates the safety of meat.

Issues for Class Discussion

1. Immediately prior to slaughter, it is important to ensure that the animal is not stressed or excited. Explain why this is so, and describe the physiological and biochemical reactions that may occur if the animal is stressed prior to slaughter. How might this impact the final meat product?
2. A wide variety of cuts of beef, veal, lamb, and pork are available, and each cut may be prepared using different cooking techniques. Explain why the leaner cuts of meat should be prepared using a moist heat method and why the well-marbled cuts of meat should be prepared using a dry heat method. What are the advantages and disadvantages of each preparation method? How does the preparation method affect nutrient retention in the final product?
3. If you were in charge of a food service establishment that served beef, lamb, and pork, which steps would you take to ensure that your product had a small carbon footprint? How would you market your product so that consumers knew that your establishment was “going green”?

Research Areas for Students

1. The health and financial benefits and drawbacks of using organic animal feed versus synthetic animal feeds
2. The biochemical changes that occur during rigor mortis
3. The public health significance of recent foodborne illness outbreaks related to ground beef and other meat products
4. The carbon footprints of beef, veal, lamb, and pork production
5. The Clean Water Act’s impact on animal feeding operations (AFOs)
6. Food safety practices recommended by the National Restaurant Association and other related organizations with regard to the serving of meat and meat products in restaurants

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