OBJECTIVES

After studying this chapter, you will be able to:

1. Describe the structure and composition of muscle, connective tissue, and fat.
2. Identify the pigments in meat and the changes that occur during heating and cutting.
3. Discuss the factors determining meat quality.
4. Identify meat cuts, grades, and the marketing process.
5. Explain the methods of meat cookery and the rationale for using each.
6. Identify various modified meat products.
7. Explain the composition of gelatin and its properties.

CLASSIFICATION

Flesh foods usually are categorized as meat, poultry, or fish. Meat includes all red meats from animal sources, although the only ones commonly available are beef, veal, pork, and lamb (or mutton in some countries). Poultry is the inclusive term for turkey, chicken, and duck, as well as pheasants and other less available fowl. Fish, in the broad sense, designates aquatic animals, but frequently it is the more narrow classification that includes only fish with fins, gills, a backbone, and a skull. Shellfish, the other classification of aquatic animals, is subdivided into mollusks and crustaceans, the former having a shell and the latter a horny covering.

FOOD FOR THOUGHT

Fish and the Environment

The public has heard the message of the health benefits of omega-3 fatty acids, which are found in abundance in seafood. Increased consumption of these fish has created concern about overfishing of various popular fish, and limits have been placed on the take for both commercial and sport fishermen. Nature also plays a significant role in determining when and where seafood will thrive. Water
temperatures in the oceans have been changing. Measurements taken by the National Oceanic and Atmospheric Administration (NOAA) along the Pacific Coast indicate that water temperature recently has been rising faster than it did at the beginning and during much of the past century.

Fishermen are reporting changes in the types and numbers of seafood in their locales. Humboldt squid and marlin, normally found in waters off Baja California, are now being caught as far north as Washington; the squid population found near San Francisco is increasing rapidly. San Diego fishermen are reporting reduced numbers of albacore, but more yellowfin tuna (the kind valued for making sushi). Fishermen off the coast of Oregon and Washington have been dealing with significant limits on the salmon they can take home; the good news is that more albacore tuna are found in this region as warmer waters have promoted their movement northward.

In the East, some people blame the warming water in Chesapeake Bay for causing an illness (mycobacteriosis) in bass living there. Algae are flourishing and taking some oxygen from the water, which may be a factor in the health of the bass population. Reduced oxygen content in the water is a potential problem in coastal waters and can cause a drop in the number of fish on both coasts in the future.

Predictions on the extent of glacial melt and the long-term effects on sea level suggest that present marshlands along the coast may disappear as the water gets deeper, and the area is transformed into open sea. When this happens, the population of crabs, shrimp, and menhaden, as well as some other types of sea life that reproduce in the sheltered marshy setting, will be reduced. These are some of the problems that need to be monitored and alleviated as much as possible to avoid losing valuable variety and quantities of seafood to feed the nation.

Quite a different environmental problem is developing for fish in the Great Lakes. The current situation has evolved from importing of some Asian carp by a fish farmer in Arkansas in 1972. The imported carp were effective in keeping holding pens clean and caused no concern until flooding in the 1990s released them into local streams. Unlike the common carp, which were already there and weighed around 25 pounds, the Asian carp ate voraciously and displaced most of the native fish as they worked their way north in streams and rivers. These giant fish may weigh as much as 100 pounds, and they are so strong that they can injure people in small boats when they soar as high as 8 feet out of the water. Not only are these giant carp badly behaved, they don’t even taste good and are full of bones, all of which removes them from the risk of appearing on dining tables. In other words, they are a menace to the edible fish supply (Figure 12.1) and to hapless boaters. Now giant carp have arrived in Chicago, where vigorous and costly efforts are being made to keep them from escaping into Lake Michigan. This effort amounts to environmentalists’ last chance to protect all of the Great Lakes from giant Asian carp. Failure to stop them will have a devastating impact on the fishing industry and sport fishing in all of these lakes.
STRUCTURE

Muscle Tissue

Components Water is the primary constituent in muscle; actually, it is about 75 percent water. The next most abundant substance, protein, is a distant second, constituting only about 18 percent of the total. The amount of fat is highly variable, but commonly ranges from 4 to 10 percent. Carbohydrate, primarily in the form of glycogen plus a small amount of glucose and glucose 6-phosphate, accounts for a little more than 1 percent of the total. Vitamins, minerals, and trace amounts of various organic compounds complete the picture.

The specific composition of muscle tissue varies from muscle to muscle and even from one spot to another within a muscle. This variation makes the testing of meats a challenging task. Additional complications occur because of the differences between carcasses.

Proteins The three most abundant muscle proteins are myosin, actin (in two forms—G-actin and F-actin), and tropomyosin. Actin and myosin can unite to form an important myofibrillar protein called actomyosin. This reversible reaction, catalyzed by adenosine triphosphate (ATP) and the presence of calcium and magnesium ions, occurs during contraction and relaxation of muscle tissue.

Enzymes contribute to the total protein found in muscle tissue. Soluble adenosine triphosphatase in the sarcoplasm (jelly-like protein in muscle fibers) is the enzyme that catalyzes postmortem lactic acid formation, causing a drop in the pH of tissues that may be largely responsible for the onset of rigor mortis. Cathepsin and calcium-activated factor are important because of their probable role in proteolytic reactions leading to the softening of tissue as rigor mortis passes. Neutral pyrophosphatase may influence the water-holding capacity of meat.

Organization The structure of muscle tissue is quite complex in its organization; it begins with the association of protein molecules (including myosin and actin) into myofilaments and continues as these initial structures associate with increasingly larger structures until finally the complete muscle is defined (Figure 12.2).

Connective Tissue

Proteins Four categories of materials are abundant in the connective tissue of meats. All of these are either pure protein or conjugated protein compounds. Of the four, collagen is perhaps the most important. The others are elastin, reticulin, and ground substance. Collagen is importance in meats because it is the fibrous protein found in the structural sheaths both within and between muscles. It is a rather complex protein that contains strands of tropocollagen, which are produced by the cells and then transferred to the ground substance for actual integration into molecules of collagen. Tropocollagen is a fibrous, coiled molecule consisting of three strands linked together to make a long, thin unit (Figure 12.3).

The presence of an abundance of hydroxyproline and proline (about 25 percent) accounts for the fibrous nature of tropocollagen, because the linkage of this amide through the pyrrolidine ring sterically hinders the molecule from assuming the usual helical configuration that leads to a spherical protein. In other words, the nitrogen in either proline or hydroxyproline is involved in the primary structure (the backbone chain) of the strands of tropocollagen, and the planar rigidity of the pyrrolidine ring prevents the bonding angles that lead to the usual \( \alpha \)-helix and ultimate spherical nature of most food proteins. This rigidity is significant because of the unusually large quantity of the two pyrrolidine-ring amino acids, proline and hydroxyproline, as shown here.
The other unique aspect of the chemical composition of tropocollagen is that it contains a large amount of the extremely simple amino acid glycine. Actually, a third of the molecule is glycine. A variety of amino acids constitute the remaining approximately 42 percent of the amino acids in tropocollagen.

The formation of hydrogen bonds causes the association of the three strands to form the tropocollagen molecule. In turn, these molecules are held in the larger collagen molecule as a result of a combination of bonding forces, including hydrogen bonding. The stability of
the native collagen molecule is due in large measure to the formation of covalent bonds that cross-link the three strands of tropocollagen to form a molecule of collagen. The number of covalent bonds formed between the three tropocollagen constituents increases gradually over time, which helps explain the increasing toughness of the meat from animals as they grow older.

**Elastin**, in contrast to the relative abundance of collagen, is found in limited amounts intramuscularly. The yellow color of elastin distinguishes it from collagen, which is white. Unlike collagen, which can be converted to gelatin during cooking, elastin is resistant to chemical change. The rubbery character of elastin accounts for its name. Two unusual amino acids, desmocine and isodesmocine, provide important structural contributions to elastin because their tetracarboxylic–tetraamino acid functional groups permit them to cross-link with as many as four chains of amino acid residues. Only a somewhat limited amount (less than 3 percent of the total protein) of hydroxyproline is found in elastin.

**Ground substance** is a protein-containing material in meat; its main constituents are plasma proteins and glycoprotein, including amino acids with excess carboxylic acid groups. In contrast to collagen, ground substance proteins are low in glycine and void of proline. Interestingly, it is apparently in ground substance that three tropocollagen strands are cross-linked securely so that collagen molecules form. The proteins in the ground substance
Part 4 Proteins

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Reticulin
A type of connective tissue protein associated with a fatty acid (myristic acid).

Endomysium
Delicate connective tissue found between fibers.

Perimysium
Connective tissue surrounding a bundle of several fibers.

Epimysium
Connective tissue surrounding an entire muscle (many bundles of fibers).

Myotomes
Fibers in fish; these are thick and about 3 centimeters long.

Myocomatta
Sheet-like connective tissue in fish.

Glycolipid
Molecule with a sugar moiety and a lipid portion.

Phospholipid
Complex phosphoric ester of a lipid.

Frequently are bound tightly to mucopolysaccharides, and these glycoproteins form an amorphous matrix in which collagen and elastin can be held to form connective tissue.

Reticulin is the fourth type of protein in connective tissue. Although it is a fibrous protein similar to collagen, the linkage with myristic acid (a 14-carbon fatty acid) clearly distinguishes it from collagen.

Organization The endomysium, consisting of ground substance and collagen, is the connective tissue between muscle fibers. The perimysium holds several fibers together. Finally, many of these bundles of fibers are gathered into large collections of fibers and surrounded by the epimysium, the outermost layer of connective tissue. These structures are the muscles in meats (Figure 12.4).

Fish flesh is structurally similar to that of red meats. Myofibrils (myotomes) in fish are much like those found in red meats, except that some (but not all) of the myofibrils in fish muscle are flat, rather than cylindrical. The ultimate level of organization in fish tissue is parallel layers of short, thick myofibrils attached to myocomatta (connective tissue in fish). The actin and myosin levels (and consequently the actomyosin level) are not only higher in fish than in red meats, but the actomyosin and collagen in fish also are more sensitive to heat. These characteristics dictate the need for careful temperature control when preparing fish.

Fat
Lipids occur in muscle tissue and also in fatty deposits or fat depots. The fatty acids found most abundantly in the triglycerides in the fat depots are oleic (18 carbon atoms, 1 double bond), palmitic (16 carbon atoms, no double bonds), and stearic (18 carbon atoms, no double bonds). In the cells, the lipid and lipid-related compounds include cholesterol, glycolipids, phospholipids, plasmalogens, and sphingomyelin. These lipid components are deposited in fat cells in a matrix of connective tissue, primarily collagen. The presence of fat contributes to the perception of juiciness and flavor of meats, and it also is of interest from the perspective of nutrition.

Beef fat, with its comparatively high content of saturated, long-chain fatty acids (Table 12.1) is quite different from pork, lamb, or various types of poultry and fish. Nutritional concern regarding the composition of fats in flesh foods has generated interest in the content of omega-3 fatty acids. Omega-3 fatty acids are particularly abundant in fish oils.

Changes in fats during storage or cooking can affect the flavor and aroma of the food (see Chapter 8). Phospholipids are particularly susceptible to chemical changes. Oxidative rancidity may increase with the presence of phospholipids. Chemical changes may occur as a result of high temperatures in deep-fat frying and broiling, particularly if the time is extended.

Figure 12.4 Diagram of a cross section of muscle.
Table 12.1  Fat Components of Selected Foods (g/100 g edible portion)a

<table>
<thead>
<tr>
<th>Food</th>
<th>Total Fat</th>
<th>Total Saturated</th>
<th>Total Mono Unsaturated</th>
<th>Total Poly Unsaturated</th>
<th>Cholesterol (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef, chuck, raw</td>
<td>18.0</td>
<td>7.254</td>
<td>7.697</td>
<td>0.684</td>
<td>91</td>
</tr>
<tr>
<td>Lamb, leg, raw</td>
<td>17.1</td>
<td>7.430</td>
<td>7.000</td>
<td>1.350</td>
<td>69</td>
</tr>
<tr>
<td>Chicken, light, no skin, raw</td>
<td>1.63</td>
<td>0.370</td>
<td>0.480</td>
<td>0.400</td>
<td>57</td>
</tr>
<tr>
<td>Chicken, dark, no skin, raw</td>
<td>3.51</td>
<td>0.930</td>
<td>1.120</td>
<td>0.900</td>
<td>72</td>
</tr>
<tr>
<td>Turkey with skin, raw</td>
<td>1.93</td>
<td>0.459</td>
<td>0.477</td>
<td>0.411</td>
<td>67</td>
</tr>
<tr>
<td>Ocean perch</td>
<td>1.54</td>
<td>0.273</td>
<td>0.475</td>
<td>0.009</td>
<td>52</td>
</tr>
<tr>
<td>Salmon, sockeye</td>
<td>6.34</td>
<td>0.981</td>
<td>2.103</td>
<td>2.539</td>
<td>55</td>
</tr>
<tr>
<td>Crab, Alaska king</td>
<td>0.60</td>
<td>0.090</td>
<td>0.080</td>
<td>0.130</td>
<td>42</td>
</tr>
<tr>
<td>Scallop, Atlantic</td>
<td>0.49</td>
<td>0.128</td>
<td>0.048</td>
<td>0.130</td>
<td>24</td>
</tr>
</tbody>
</table>


PIGMENTS

Myoglobin and Related Compounds

The two key pigments responsible for the color of meats are hemoglobin and, more prominently, myoglobin. Actually, myoglobin and hemoglobin are closely related chemically, for they both are iron-containing pigments with heme as the common component. They differ only in their protein component. In contrast to hemoglobin with its four polypeptides, myoglobin has only one strand of protein polymer and a molecular weight of about 17,000.

Hemoglobin is about four times as large as myoglobin. It consists of four heme-polypeptide polymers joined together. Heme contains four pyrrole rings linked covalently to form a large complex that is joined to a central atom of iron by attachment to the nitrogen atoms in each of the pyrrole rings (Figure 12.5). In turn, four heme-polypeptide polymers also are linked to make the large molecule designated as hemoglobin. Its molecular weight is approximately 68,000.

Hemoglobin
Large, iron-containing compound consisting of four heme-polypeptide polymers linked together; contributes to meat color.

Myoglobin
Purplish-red pigment consisting of heme-containing ferrous iron and a polypeptide polymer (globin).

Heme
Compound composed of four adjoining pyrrole rings linked to an atom of iron.

\[ \text{Heme} \]

Figure 12.5  Structure of heme (and the abbreviated representation).
The iron atom in the center of heme can complex with other atoms or compounds to form new compounds, resulting in alterations in the color of the meat. Other color changes result from changes in the valence of the iron atom itself.

Myoglobin is of particular interest in the study of meat color because it is the predominant pigment and contributes about three times as much color as does hemoglobin. The purplish-red color of myoglobin is seen because iron is in the ferrous (2+) state and free of additional atoms or compounds. When meat is fresh and protected from contact with air, the dominant color is the purplish-red color of myoglobin.

In the presence of air, myoglobin readily adds two atoms of oxygen to form a new compound, oxymyoglobin, which is responsible for the rather intense red seen on the cut surface of meat that has been exposed to air for a while. Availability of an abundance of oxygen favors the formation of oxymyoglobin and ensures that meat will have a pleasingly bright red color.

The use of a plastic wrap permeable to oxygen for packaging precut meats helps ensure that the cuts will have the bright red color of oxymyoglobin that appeals to consumers. Tetrasodium pyrophosphate, sodium erythorbate, and citric acid are an effective combination to maintain oxymyoglobin longer when meat is marketed in modified-atmosphere packaging.

If the oxygen supply available to myoglobin is rather limited or meat is exposed to fluorescent or incandescent light too long, a brownish-red pigment, metmyoglobin, forms. This less desirable color results from oxidation of the iron atom to the ferric (3+) state and complexing of a molecule of water. Metmyoglobin can be reduced back to myoglobin. Depending on the environment, myoglobin pigments may be converted between oxymyoglobin, myoglobin, and metmyoglobin according to the following scheme:

In contrast to the red color of various animal meats, fish and poultry generally are pigmented quite lightly. Hemoglobin contributes to the light coloration in poultry. Quite a few vertebrate fish have two muscles—a light-colored, large lateral muscle and a less desirable dark muscle deeply pigmented with myoglobin. The lateral muscle in salmon derives its unique color from the presence of astaxanthin, which is classified as a carotenoid pigment.

### Changes Effected by Heating

While red meat cooks, heat changes the pigments. First, the myoglobin present in the interior of muscles changes to oxymyoglobin. Continued heating converts the oxymyoglobin into denatured globin hemichrome, the grayish brown associated with well-done meats. Denatured globin hemichrome is the counterpart of metmyoglobin, but heat has denatured the protein (globin) component. This reaction is illustrated here:

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**Oxymyoglobin**
Cherry red form of myoglobin formed by the addition of two oxygen atoms.

**Metmyoglobin**
Brownish-red form of myoglobin formed when the ferrous iron is oxidized to the ferric form and water is complexed to the oxidized iron.

**Astaxanthin**
Reddish-orange carotenoid pigment in salmon and in cooked crustaceans.

**Denatured globin hemichrome**
Myoglobin derivative formed when heat triggers the oxidation of iron to the ferric (+3) state and denatures the globin portion of the compound while the oxygen of oxymyoglobin is replaced with water complexed to the iron atom, resulting in a gray-brown color.
Heating enhances the light color of fish by increasing opacity, but this is not a dramatic change. Quite a different situation occurs with crustaceans, for the drab, blackish-green color of uncooked crab, lobsters, and shrimp changes as astaxanthin becomes dominant and the former predominant pigment loses its effect due to denaturation of the protein with which it is complexed.

As is true with fin fish, poultry ordinarily is essentially colorless when cooked. If young poultry has been frozen and some hemoglobin has leaked from the marrow, there may be some hemoglobin in the flesh close to the bones, which becomes dark when cooked. Sometimes poultry that has been subjected to intense heat during preparation develops a reddish-pink color. This is the result of hemoglobin reacting with carbon monoxide and nitric oxide generated by an electric heating element or flames when barbecuing.

**Changes Effected by Curing**

Meats sometimes are cured; this process usually involves treatment with sodium nitrite and salt to preserve meats for long-term storage. Bacon is cured by pumping or dry curing; the former is done by injecting the curing agents and waiting for 5 to 24 hours before cooking the bacon slowly, whereas dry curing requires several days of curing before heating. One of the important functions of nitrite is to prevent botulism in cured meats (see Chapter 16). Sodium ascorbate or sodium erythorbate are also required to be added to pumped bacon because vitamins C and E reduce the levels of nitrosamines that form during frying bacon and nitrite-cured meats.

Of particular interest in a discussion of pigments is the effect of nitrites on meat color. The nitric oxide, which forms from the nitrites in meat curing, combines with myoglobin to form nitric oxide myoglobin. This compound changes to nitric oxide myochrome when a second nitroso group replaces the globin during the slow heating involved in curing. Nitric oxide myochrome is a key pigment in cured meats and contributes to the stability of their familiar pinkish-red color. Exposure to light and air causes oxidation of the ferrous iron to the ferric (3+) state, which results in development of a brownish color.

Nitrosyl-hemochrome forms during the curing of meats when a nitroso group joins with myoglobin, and heat denatures the globin portion of the molecule. This compound also is a pink pigment abundant in cured meats. On oxidation of the iron in nitrosyl-hemochrome, the pigment structure changes to that of denatured globin nitrosyl-hemochrome, which is brownish. The reactions during curing are as follows:

![Chemical reactions diagram]

Exposure to light and additional oxygen hastens the breakdown of pigments in cured meats. In particular, light promotes removal of the nitroso group from pigments. This sets the stage for oxidation of ferrous pigments to the ferric state, with the resulting discoloration. Occasionally, the porphyrin ring is oxidized, which leads to fading of pigments and sometimes development of a fluorescent green or yellow color. The almost rainbow-like appearance occasionally noted on the surface of packaged cured meats may result from the way light is refracted from the pigments.
MEAT QUALITY

Factors Affecting Quality

Maturity  The physical changes that occur from the time an animal is born until it is slaughtered affect the characteristics of the resulting meat. Young animals have a comparatively low ratio of lean to bone. They also have a relatively large amount of connective tissue and little fat. These characteristics can be seen in veal, which comes from animals not more than three months old. Somewhat greater range is seen in lamb, which comes from animals up to the age of 14 months. However, mutton is more than two years old. Unlike the distinctions made for different ages of both cattle and sheep to facilitate marketing, pork generally is from animals that are six months or just slightly older.

The increased fat content of mature animals influences the flavor of the meat and contributes to apparent juiciness, an important contribution because moisture content decreases. Connective tissue within the lean tissue increases in total amount as an animal matures, but it is present in somewhat smaller percentages than those when the animal was very young. Despite this small shift, meat from mature animals may be less tender than a comparable cut from a young animal. This decrease in tenderness may result from increased formation of cross-linkages between the fibers of collagen within the lean muscle as the animal matures and grows older.

As cattle age, beef flavor undergoes change. Fat content influences this, but other changes also may contribute to the stronger characteristic flavor of mature beef. The color of the muscles gradually becomes redder and sometimes darker. The pH of muscle also may decrease. Differences between carcasses make information regarding changes caused by maturation difficult to verify.

Postmortem Changes  Biochemical processes in a carcass continue several hours after slaughter and influence the quality of meat. The level of glycogen stores in the animal at the time of slaughter is paramount in determining onset of rigor mortis and key palatability factors in the meat when it is ready to be marketed. Glycogen is important because this complex carbohydrate undergoes biochemical degradation to produce lactic acid after slaughter.

Desirably, the pH in the flesh of cows and other mammals drops due to lactic acid formation from approximately neutral (commonly, pH 7.0 to as high as 7.2) to a pH of about 5.5 (only pH 6.2–6.5 in fish). This is about at the isoelectric point of the proteins, which causes the fibers to tend to pack together and force out some of the water. Moisture level in meat is important because of its influence on the juiciness of the cooked product.

The time of onset of rigor mortis differs among species and even a bit among carcasses of the same species. Fish may begin to develop rigor mortis an hour after being killed, although onset may be delayed by as much as 7 hours. Rigor mortis is extended in fish if they are iced as soon as they are killed and maintained in a chilled storage environment. This extends the time that fish remain fresh, because bacterial spoilage commences only after rigor mortis has passed. However, even careful icing during storage cannot extend the storage time of fresh fish more than about a week from the time of death.

The various muscles in beef exhibit different behavior; some need to be aged 11 days before achieving maximum tenderness. During this aging period, desirable storage conditions include ultraviolet light to control growth of microorganisms, a controlled humidity of 70 percent, and a temperature just above freezing. These measures are important to keep the meat from becoming microbiologically unsafe or too dry. However, beef may be held at a temperature of 16°C (61°F) for between 16 and 20 hours after slaughter before being aged at 2°C (36°F) to promote tenderness.

Aging of Beef  Beef may be held for several days or even longer to enhance tenderness due to action of cathepsins and calcium-activated factor (proteolytic enzymes) that

Rigor mortis  Temporary rigidity of muscles that develops after death of an animal.
produce simpler proteins and break some linkages between actin and myosin. Clearly, aging promotes the development of tenderness in beef.

### Inspection and Grading

Federal inspection is mandatory for slaughter and interstate marketing of all meat, although state laws apply if meat will not be crossing state lines. This is done to assure that the animal was not diseased and that adequate sanitation standards and temperature controls have been maintained so that the meat is safe when it is shipped to market. A federal inspection stamp on the area of each primal cut is evidence of the appropriate inspection for meat safety (Figure 12.6).

Quality of meat usually is determined by federal graders, who evaluate carcasses according to established criteria based on such physical characteristics as marbling, texture, and yield (Figure 12.7). Thus, grade designation is a guide to palatability, but does not indicate safety. Table 12.2 lists the grades for various types of meats.

### Identifying Meat Cuts

In the marketplace, meats are cut and named according to industry standards for beef, veal, pork, and lamb. Carcasses are first carved into large primal cuts, each of which will bear the federal inspection stamp if entering interstate markets. Subsequently, the primal cuts are subdivided into retail cuts and labeled according to established standards. Consumers are able to anticipate the characteristics they can expect in a particular cut if they read the identifying label and know grading standards and the anticipated tenderness from the specific primal cut (Figure 12.8).

Researchers conducting studies on meat need to describe the meat cuts used by identifying the species, approximate age (if known), presence (or removal) of bone, cut (if a standard retail cut, according to the Uniform Retail Meat Industry Standard), and specific muscles studied. For research purposes, the names of various muscles are used to identify the exact muscle from a cut that is tested. This identification is necessary because of the variation in physical properties found in the different muscles within a single cut, as can be seen by comparing the relative tenderness scores. Results of shear tests (reported in pounds required to shear the muscle) showed that psoas major was the most tender and the internal oblique was the least tender of the muscles tested: the smaller the value, the more tender the muscle (Table 12.3).

The psoas major, commonly referred to as the tenderloin, and the longissimus dorsi are two muscles often used in meat research, but the T-bone steak that contains these two muscles also may include the gluteus medius and the internal oblique muscles. The longissimus dorsi is such a long muscle that it also is the principal muscle in standing rib roast. In contrast to the limited number of muscles in cuts from the rib and short loin, round steak has several muscles: rectus femoris, adductor, semimembranosus, semitendinosus, biceps femoris, and vastus lateralis (Figure 12.9).
MARKETING

Fresh/Frozen

Meat, poultry, fish, and shellfish that are available in retail markets may have been produced in the United States or may have come from distant places such as Thailand, Vietnam, and New Zealand. Products from distant ports often are frozen so they can be shipped as economically as possible; some domestic products also are frozen prior to the marketing process. Freezing retards deterioration of these protein-rich foods and extends their shelf life.
### Table 12.3  Relative Tenderness of Selected Muscles as Measured by Shearing

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Force Needed to Shear (Pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Porterhouse steak</strong></td>
<td></td>
</tr>
<tr>
<td>Psoas major</td>
<td>7.2</td>
</tr>
<tr>
<td>Longissimus dorsi</td>
<td>7.9</td>
</tr>
<tr>
<td>Gluteus medius</td>
<td>7.5</td>
</tr>
<tr>
<td>Internal oblique</td>
<td>12.6</td>
</tr>
<tr>
<td><strong>Round steak</strong></td>
<td></td>
</tr>
<tr>
<td>Adductor</td>
<td>10.0</td>
</tr>
<tr>
<td>Semimembranosus</td>
<td>12.0</td>
</tr>
<tr>
<td>Semitendinosus</td>
<td>11.0</td>
</tr>
<tr>
<td>Biceps femoris</td>
<td>10.7</td>
</tr>
<tr>
<td>Vastus lateralis</td>
<td>11.4</td>
</tr>
<tr>
<td>Rectus femoris</td>
<td>9.0</td>
</tr>
</tbody>
</table>


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**Figure 12.9**  Muscles in porterhouse steak and round steak.
Labeling regulations require manufacturers to inform consumers about the previous temperature treatment of meat, poultry, fish, and shellfish displayed for sale. Products marketed as “fresh” must never have reached a temperature below −3.3°C (26°F). Poultry and other flesh foods chilled to −3.3°C (23°F) are still pliable but are very close to being frozen.

At retail markets some poultry, fish, and meat items are identified as previously frozen. These items have been frozen at −17.8°C (0°F) and then allowed to thaw to at least −3.3°C (26°F). This tells consumers that the textural changes that occur in frozen products will be present. It also signals the need to prepare the item fairly soon and to avoid refreezing it.

**FOOD FOR THOUGHT**

**Kosher/Halal**

Niche markets provide the opportunity for developing food to meet the specific requirements of a particular group of consumers. However, the goal of the company making the food may be to sell to others beyond that relatively small market, as well. For many years, kosher meats, dairy, and a variety of baked and other food products have been produced according to kashruth (Jewish dietary laws) and certified as kosher, a designation shown on each package. Buyers of kosher foods include Jews and many other people who are seeking the oversight in production and/or the pleasure of eating a food they enjoy. Approximately 86,000 food products bearing the kosher designation now appear in markets in the United States.

The recent increase in the Muslim population in the United States is beginning to create a niche market for foods labeled as halal (meats and food products that have been prepared for market meeting Muslim dietary laws). Both kashrut and halal certifications require that meats (pork is prohibited for both) and poultry be butchered and bled according to the ritual specified, which differs with the religion. Predictions are that food products labeled as halal will begin to make their way into supermarkets across the nation soon.

**Domestic/Foreign**

Meat, poultry, fish, and shellfish available to consumers come from domestic and foreign sources. Entry of imported products is of interest not only to U.S. customs officials but also to the various other federal agencies (e.g., USDA and FDA) responsible for safeguarding the nation’s food. Regulations that permit entry into the national food supply are of great importance because of the potential for imported foods to be unsafe for human consumption (Figure 12.10). The American public expects all foods in the marketplace to be safe to eat. Standards for safety and sanitation of food vary widely in various countries, thus creating a large challenge to those involved in assuring that imported meats and other foods are safe.

Sodium and potassium lactate may be added to meats to inhibit growth of *Clostridium botulinum*, *E. coli* O157:H7, *Salmonella*, and *L. monocytogenes* and help extend the shelf life of meats. Diacetate may be used in conjunction with lactate salts because the two together are particularly effective against *Listeria* in meats that are marketed as ready to eat. Lactates also help retain the red color of beef during marketing.

**INGREDIENT INSIGHTS**

**Apples and an Antimicrobial Edible Film**

An edible film made using apple peels, carvacrol (from oregano), and cinnamaldehyde (from cinnamon) is being tested for possible use in commercial meat packaging and in homes. The purpose is to retard growth of harmful microorganisms (notably, *E. coli* and O157:H7 *Listeria monocytogenes*) on meat during storage. The benefits of using such a film as a wrap for meats could be twofold: improved food safety and a commercial product that generates income from material that would become waste.
Contamination of fish because of environmental pollution has triggered extensive efforts to clean up the environment. Particular concerns regarding industrial and human waste contamination resulted in cleaner water in streams, rivers, and even parts of the ocean. Although these efforts need to continue, levels of contamination in wild and farmed fish that are sent to market are monitored and are deemed to be safe for human consumption. The levels of polychlorinated biphenyls (PCBs) in farmed salmon are well within the recommended range for safety and are not considered to be a risk.

A particularly graphic example of international food safety concerns is the continuing effort to stamp out mad cow disease. Only a very few cases of Creutzfeldt–Jakob disease in humans have occurred in Europeans who had eaten beef linked to mad cow disease. Attempts to control bovine spongiform encephalopathy (BSE), or mad cow disease, have been ongoing in Europe and many other parts of the world where cattle are raised. This vigilance has been quite effective in reducing the problem, but one case was discovered in Canada in 2015.

**Carcass/Case-Ready**

Traditionally, beef, veal, pork, and lamb carcasses or sides of beef have been shipped to markets where they are hung in a chilled room until the store’s butcher(s) cut and package them for customers. Today, large quantities of case-ready meats are available in markets throughout the nation. Case-ready meats are prepared and packaged in large facilities in which safety is monitored carefully according to the Hazard Analysis and Critical Control Points (HACCP) procedures approved for each facility.

One of the compelling reasons for the production of case-ready meats is the quality of review and enforcement of sanitation standards that are possible. Oversight of these

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**Mad cow disease**

Common name for bovine spongiform encephalopathy (BSE).

**Case-ready meats**

Meats that are processed and packaged in retail packaging at a centralized site for distribution to retail markets.
facilities can be done efficiently because the number of sites is quite small compared with
the number of smaller meat markets throughout the nation.

Developments in preparing case-ready meats produce products that can be put on sale
in display cases without additional handling and packaging by butchers in retail stores. Packaging materials and techniques are constantly studied as the industry works to extend the retail shelf life beyond the few days that are assured presently. Extended shelf life helps keep meat costs down. Labor costs also are kept to a minimum with case-ready meats because of the efficiencies in use of labor at the large processing and packaging centers.

**FOOD FOR THOUGHT**

**Shrimp Ahoy**

Shrimp from the Gulf of Mexico are a familiar commodity in fish markets, but a combina-
tion of a “dead zone” in the Gulf and imports from Latin America and Asia (from shrimp farms and the sea) is challenging shrimp fishermen in the Gulf. Shrimp have been dying in a huge area (dubbed the “dead zone”) of the Gulf along the coast of Texas and Louisiana. Shrimp deaths in this area are due to lack of oxygen in the water, a condition that has varied over the past two decades.

The problem can be traced to the fertilizers used on farms in the Midwest. Fertilizer residues and other pollutants ultimately drain into the Mississippi River and finally into the Gulf of Mexico, where algae thrive on these pollutants. The formation of huge blooms of algae depletes the ocean water of the oxygen that shrimp and other ocean species need to live, which creates the dead zone. The size of the dead zone varies from season to season. Surprisingly, the dead zone in the summer of 2003 was found to be much smaller, and fishermen were catching shrimp in surprising unusually large numbers.

Credit for this environmental improvement was given to the powerful storms that whipped up the waters so vigorously that waters in the dead zone were oxygenated suf-
ficiently for shrimp to flourish once again. Although these severe storms wreaked havoc on other sectors of the economy along the Gulf, they clearly sparked the shrimp market. Nevertheless, improvements in preventing pollution of the waterways also are necessary to protect the Gulf fishing industry. Unfortunately, the problem is far from solve. In 2015 governmental regulation of pollutants entering the Mississippi River was being consid-
ered to try to reduce the environmental impact on the Gulf and its aquatic inhabitants.

**PREPARATION**

**Changes Effected by Heat**

Fat melts and proteins are denatured when meats are heated. The overall effect on palat-
ability depends on the conditions used in heating the meats. Water is lost while cuts heat. Initially during heating, some bound water converts to free water as the water-binding capacity of the meat is reduced. This newly available free water offsets the water lost in the early period of cookery, and the meat remains juicy. When meat reaches temperatures between 74 and 80°C (165 and 176°F), the well-done stage, bound water is converted to free water very rapidly. However, the water loss exceeds the water available from this conver-
sion, resulting in reduced juiciness.

Muscle fibers undergo changes in dimensions as a result of heating (Figure 12.11). Shrinkage in their width begins to occur soon after heating begins and is completed at a temperature of 62°C (144°F); water-binding capacity also is reduced. The narrowing width of fibers appears to result from the unwinding of the tertiary structure of the proteins, a change that is followed by cross-linkage of the coagulating proteins, causing shrinkage of the length. Fibers begin to shrink lengthwise at about 55°C (131°F) and continue until about 80°C (176°F).
Muscle proteins in meat become less tender when heated. This toughening is a two-step process. When meat fibers are heated to between 40 and 50°C (104 and 122°F), myosin becomes less soluble, and hydration of myosin and other muscle proteins decreases. The second phase affecting the tenderness of muscle proteins occurs when they reach temperatures between 65° and 75°C (149° and 167°F).

Other changes in muscles ensue. Gaps in the actin filaments of the I band in the biceps femoris and semimembranosus of round steak slowly lead to a granular or mealy character because of the large amount of structural disintegration. In contrast, the longissimus dorsi of the rib and short loin tends to form an increasingly solid and less tender muscular mass as the temperature rises.

Connective tissue in meats also needs to be considered in a discussion of the tenderness of cooked meats. Elastin is not modified, but collagen molecules slowly change when subjected to moist heat, because hydrogen bonds begin to break between the component tropocollagen strands. This permits some movement within the collagen molecules, and the gelatin components of collagen begin to move away from each other. Evidence for this formation of gelatin can be seen when drippings from a pot roast are refrigerated, causing the gelatin to form a gel.

Conversion of collagen to gelatin has a considerable effect on the tenderness of meat cuts heated for an extended period, which occurs when preparing less tender cuts. The length of time that meat is held above 65°C (149°F) is important in promoting collagen conversion to gelatin.

Clearly, the tenderizing effect of heating collagen for an extended period is opposed by the toughening effect of heat on muscle proteins. Optimal preparation of a particular cut

Figure 12.11 Some shrinkage occurs during roasting, causing the ends of the bones to be more visible than they were before being heated.
requires a choice of cookery compatible with the meat’s composition. If collagen content is high, as is true in less tender cuts, extended heating is desirable to permit considerable conversion of collagen to gelatin. This tenderizing action will more than compensate for the toughening of the muscle proteins that occurs at the same time.

Tender cuts of meat will become less tender with extended heating if the meat reaches temperatures above 60°C (140°F). This effect is the result of the toughening of the muscle proteins, a change that cannot be offset by the conversion of limited amounts of collagen to gelatin.

The importance of the opposing effects of collagen and muscle proteins during heating is seen particularly clearly in the preparation of fish. Only a small amount of collagen occurs in fish, which means that the major effect of heating is change in muscle proteins. By heating fish just until it flakes, some softening of collagen occurs to permit easy separation of fibers while some denaturation of the muscle proteins also occurs. At this point, the fish flesh is still tender. Continued heating increases toughness, the result of continuing detrimental changes in the muscle proteins.

Overcooking of fish causes considerable loss of palatability. The temperatures used for cooking fish are quite unimportant in determining the quality and overall palatability of the finished product as long as heating ceases as soon as the fish muscle can be separated into flakes. However, overcooking is more likely to occur when high temperatures are used because of the rapid rise in temperature of the fish.

**Dry Heat** Dry heat cookery methods (roasting, broiling, pan broiling, pan frying, and deep-fat frying) are designed to maximize the quality of muscle proteins, rather than considering the changes in collagen if heating were extended longer. Tender cuts of meat, because of their relatively high proportion of muscle protein and reduced quantity of collagen, are well suited to dry heat cookery (Figure 12.12). Only in roasting is there much opportunity to convert collagen to gelatin; cooking times for other dry heat methods are too short for effective conversion to occur. Recommended final interior temperatures are given in Table 12.4.

![Figure 12.12](image-url)  
*Figure 12.12* Turkey placed breast down in a V-shaped rack is ready to be roasted without a cover (a dry heat method).*
Chapter 12  Meats, Poultry, and Fish

Table 12.4  Recommended Safe Interior Temperatures for Selected Meat, Poultry, and Fish*

<table>
<thead>
<tr>
<th>Category</th>
<th>Food</th>
<th>Temperature (°F)</th>
<th>Rest Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground meat</td>
<td>Beef, veal, pork, lamb</td>
<td>160</td>
<td>None</td>
</tr>
<tr>
<td>Fresh beef, veal, pork, ham, lamb</td>
<td>Steaks, roasts, chops</td>
<td>145</td>
<td>3 minutes</td>
</tr>
<tr>
<td>Ham, precooked</td>
<td>Reheat</td>
<td>140</td>
<td>None</td>
</tr>
<tr>
<td>Poultry</td>
<td>Whole or pieces</td>
<td>165</td>
<td>None</td>
</tr>
<tr>
<td>Seafood</td>
<td>Fin fish</td>
<td>145b</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Crustaceans</td>
<td>c</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Oyster clam, mussel</td>
<td>d</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Scallop</td>
<td>a</td>
<td>None</td>
</tr>
</tbody>
</table>

*Adapted from FoodSafety.gov recommendations.
†Cook until flesh is opaque and separates easily with a fork.
‡Cook until flesh is pearly and opaque.
§Cook until shells open during cooking.
¶Cook until flesh is milky white or opaque and firm.

The usual temperature for roasting is 163°C (325°F). This temperature produces meats that are juicy, tender, and flavorful, and the cooking losses are less than occur with an oven temperature of 218°C (425°F) or higher. Less tender roasts, such as top round, can be cooked at 93°C (200°F) to achieve a satisfactory roast. The very long roasting period required for the meat to reach an internal temperature of 67°C (152°F) enables the collagen to convert effectively into gelatin.

Broiling is a direct heat method in which meat is subjected to an intense heat until the desired degree of doneness is reached. Not surprisingly, the higher the internal temperature reached in the meat, the greater are the cooking losses. When thick pork chops are broiled, they are less juicy than comparable chops about half as thick. For broiled ground beef patties, juiciness and tenderness decrease, while flavor improves, as the interior temperature rises. Cooking losses are greater in broiling than in microwaving, but less than in roasting.

Pan broiling is similar to pan frying except that fat is drained frequently, rather than remaining in the pan as is done in pan frying. In deep-fat frying, meats are immersed in hot fat, usually at 190°C (375°F). Meats cook rapidly by these methods; deep-fat frying causes rapid browning on the exterior, but the interior may not have reached a safe temperature. It is essential to check the interior temperature with a thermometer.

Fast-food operations and some institutional settings use restructured meats, which often are prepared by either frying or grilling. Breading is especially important for palatability if deep-fat frying is the method chosen. Broiling, grilling, or roasting produces meats that are juicier and have a better texture than results from deep-fat frying.

Bacon can be fried, pan fried, or in a microwave oven. When it is being heated, some nitrosamines form from nitrites. The more well done, the more nitrosamines formed. Although they also form during microwave cookery, the level is less.

Microwave cooking of meats results in greater cooking losses and less juiciness than when other meat cookery methods are used. This may be due to extreme tightening of protein molecules, which could force water from the meat. A potential advantage of microwave cookery of meat is reduced fat content, possibly the result of comparatively rapid heating of fat in the inner portions, which may facilitate drainage of fat from the cut. Fat, particularly fatty acids with double bonds, is agitated even faster than water when subjected to microwaving. The flavor of the outer areas of meat prepared in a microwave oven is not as appealing as comparable cuts that have been oven roasted.

Although microwave cookery of meat is essentially a dry heat method, heating of the meat occurs in a somewhat different manner than in other methods of dry heat meat cookery. Microwave heating is accomplished when microwaves cause oscillation of water and fat molecules in the meat (see Chapter 6). This heat is distributed farther into the interior of the cuts by conduction, a process that requires time. Ordinarily, meats heated in a microwave oven are prepared using a moderate setting, which automatically alternates periods of
microwaving with standing time to provide the opportunity for conduction and to enhance the equalization of heat in the cuts.

One of the shortcomings of meats prepared in a microwave oven is the unattractive gray surface. Tenderness also is affected adversely. Surprisingly, microwaved meat cuts usually are less tender than comparable cuts prepared by roasting and broiling even though microwaving reduces the cooking time. Bacon can be cooked successfully in a microwave oven, perhaps because of its high fat content.

The particular benefit of a microwave oven in meat cookery is for reheating meats that have been cooked previously. The flavor of meats reheated in a microwave oven is more appealing than that of meats reheated by traditional methods.

**Moist Heat** Moist heat, either braising or stewing, is designed to provide sufficient time for collagen to be converted to gelatin without toughening the muscle proteins unduly. The liquid in which the meat is braised or stewed prevents the surface of the meat from becoming hot enough to dry and brown excessively (Figure 12.13). Sufficient heat input is needed to maintain the liquid at a simmering temperature or even at a gentle boil, so the meat will be hot enough for collagen to begin to unwind and separate slowly into molecules of gelatin. The likelihood of evaporating all of the cooking liquid with this controlled rate of heating is minimal. As long as water is present, the meat cannot get hot enough to burn and toughen extensively.

Less tender cuts of meat that are braised or stewed until they reach and maintain an interior temperature of about 98°C (208°F) for about 25 minutes will be fork tender. Cuts that are high in connective tissue are well suited to this type of meat preparation because of their comparatively high collagen content. The increased tenderness resulting from the conversion of collagen more than offsets the toughening in the muscle proteins. Tender cuts of meat are not well suited to prolonged moist heat cookery; the comparatively high amount of muscle protein is toughened by the heat and tends to counteract the effect of collagen conversion.

![Figure 12.13](image-url) Less tender cuts of meats become tender when cooking slowly using moist heat, as was done to make this stew.
Poaching or steaming can be used to prepare fish, but the preparation time needs to be just long enough to coagulate the muscle proteins. There is so little connective tissue in fish that the muscle proteins clearly are the dominant type of protein to consider.

Crock pots or slow cookers are small electric appliances designed specifically for moist heat cookery. The temperature reached in different models varies somewhat but ordinarily is less than 107°C (225°F). Several hours are required for the interior of the meat to be heated sufficiently to tenderize the connective tissue and kill microorganisms that may be present. Meats prepared in a slow cooker are palatable, and tenderness scores are better than when a pressure saucepan is used.

In contrast to the crock pot, the pressure saucepan speeds moist heat meat cookery because the pressurization results in a hotter temperature for braising than can be achieved in a regular Dutch oven or other nonpressurized, covered pan. When braising is done in a pressure saucepan, the meat is less juicy than when a nonpressurized pan is used. Flavor and overall acceptability are not altered by use of a pressure saucepan for braising.

Sometimes meats are roasted in aluminum foil or in special roasting bags. These devices trap moisture around the meat, changing roasting from a dry heat cookery method to a moist heat one. At the oven temperatures ordinarily used for roasting, 150–163°C (302–325°F), wrapping the meat in aluminum foil increases cooking time significantly. Compared with roasts prepared without foil, foil-wrapped roasts prepared in an oven at 150°C (302°F) are less pleasing in flavor and are also less juicy and tender. Roasting bags produce results similar to those obtained using a foil wrapping.

**Cooking Losses** Cooking losses, although frequently discussed as a single entity, actually are the combination of evaporative and drip losses. Drip losses include both juices and melted fat. Evaporative losses are calculated as the difference between the weight of the uncooked meat and the weight of the cooked meat plus drippings.

Because of both the relatively high cost of meats and the reduced juiciness associated with losses during cooking, the effect of the method of meat cookery on cooking losses and the resulting impact on yield is important. Use of aluminum foil or film wrapping when heating meats causes greater cooking losses than occur when the wrapping is omitted. Cooking losses are greater for meats prepared in a slow cooker than when a faster cooking method is used.

Predictably, the higher the final temperature of meat, the greater is the cooking loss. Cooking losses for sirloin roasts heated in a convection oven are less when the oven temperature is 93°C (200°F) than when it is 149°C (300°F), and the yield also is greater, as would be anticipated. In a conventional oven, cooking losses are lower at 125°C (257°F) than at 163°C (325°F), but the long roasting period required for the lower temperature makes the higher oven temperature the one ordinarily used.

**Effects of Altering pH**

Hydration of meat is important to evaluation of juiciness in the cooked product. Adding an alkaline ingredient darkens the color of the meat by increasing pH and minimally influencing hydration. Increased tenderness does not develop, so the addition of soda is not recommended. Adding an acid is another possibility; marinating a less tender cut in undiluted vinegar for two days can result in increased juiciness and tenderness when the meat is braised. Possible negative effects on aroma, flavor, and acceptability may offset the improved tenderness and juiciness.

**Effect of Salt**

The main effect of salt on meats during preparation is enhanced water retention. This ability to hold water in the meat improves juiciness. It may have a minor role in promoting tenderness, but the overall impact of salt on palatability of meat is much too minor to outweigh the health advantage of avoiding use of excess salt.
MEAT TENDERIZERS

Meat Tenderizers

**Enzymes** Certain proteolytic enzymes can increase the tenderness of less tender cuts of meat. The most common of these is a commercial blend of enzymes from papaya and salt, a blend that is referred to simply as papain. The three enzymes in this substance are chymopapain, papain, and a peptidase. Papain is applied to the surface of the meat, and then the meat is pierced repeatedly with a fork to help carry the enzymes into the interior. Unless piercing is done, the enzymes will tenderize only the surface of the meat and a very short distance (no more than 2 millimeters) into the muscle because of the limited penetrating capability of the enzymes.

Papain has little effect at room temperature, but it becomes active when the temperature of the meat reaches 55°C (131°F) and increases in activity with additional heating to even 80°C (176°F). Activity ceases when the enzyme is denatured by heat; it is definitely inactive at 85°C (185°F).

Much of the tenderizing effect is the result of the enzyme destroying the sarcolemma surrounding the myofibrils in the fibers, hydrolyzing actomyosin, and then continuing hydrolytic breakdown of various proteins in the fiber. Collagen also may be hydrolyzed to contribute still further to the tenderizing effect. The result of this enzymatic action often is the development of a somewhat mushy texture in regions where the enzyme has acted. This is true whether or not the enzyme has been allowed to stand on the meat for a period before cooking, because the enzyme exhibits its major action in the hot meat.

Although papain is the principal enzyme used for tenderizing meats, other proteolytic enzymes also can be utilized for this purpose. For example, **bromelain** is an enzyme found in fresh pineapple. Its action sometimes occurs when the fresh fruit is an ingredient in recipes such as those for kabobs or stir-fried chicken. Bromelain is inactivated between 77 and 82°C (170 and 180°F). **Ficin**, a proteolytic enzyme in figs, is another possible enzyme for tenderizing meat.

**Mechanical Tenderizing** Commercially, meat can be run through a tenderizer equipped with needles or blades to cut some of the connective tissue and increase tenderness. This makes it possible for some less tender cuts to be used in the same way as tender cuts. Mechanical tenderization changes the texture somewhat, but it does not produce the mushy character sometimes found in cuts tenderized by enzymes.

Another means of mechanical tenderization is pounding with a meat hammer to break some of the muscle fibers and connective tissue. Yet another technique, one a bit more rigorous than pounding, is cubing. In cubing, the meat is passed through a machine that cuts through a fair portion of the muscle, a process that may be repeated to increase tenderness still more.

The ultimate means of mechanical tenderizing is a meat grinder, which is used to make ground meats. This intensive shearing of the fibers and connective tissue results in very tender meat from less tender cuts.

MODIFIED MEAT PRODUCTS

**Reduced-Fat Meats**

Consumer interest in weight control and cholesterol has created a demand for meats and meat products with reduced fat levels. An early approach toward satisfying this demand was modification of the beef grading criteria to enable beef with a comparatively low fat content to be graded as USDA Select. Now, the meat mixtures themselves are modified to formulate ground meats with a fat content as low as 10 percent.

When meats are being cut and prepared for sale, considerable trimmings containing fat and muscle accumulate. These trimmings can be heated at about 38°C (100°F), spun in a centrifuge to separate the fat from the meat, and treated with ammonium hydroxide or citric acid to kill E. coli and other bacteria that may be present. The resulting meat mixture
has a fat content of only about 5 percent. The product that uses ammonium hydroxide is called **lean finely textured beef (LFTB)** and the one adding citric acid is termed **finely trimmed beef (FTB)**. These products can be blended at a level of about 10 percent with ground meat from various beef cuts to make ground beef that is low in fat and nutritious. It is subject to the same FDA inspection as other meats. A television program in 2012 created an emotional outcry against these products that caused a significant loss of jobs and closure of three plants. Subsequently, the FDA has reviewed the processing and production and declared finely textured beef to be safe and in the marketplace. These products not only reduce waste but also help lower the cost of ground meats.

### Restructured Meats

Portion control and quality control are two major problems of purchasing meat for institutional use. **Restructured meats** provide the answer to these problems and a challenge to food technologists. Aspects of production that require careful attention include the size of the protein flakes, the amount of fat, and the content of connective tissue.

Flakes no larger than 6 millimeters produce a more desirable restructured meat than flakes a little more than twice that size. Large pieces of connective tissue are detrimental to the quality of the product. Although the resulting products are not identical to regular meat cuts, restructured meats are sufficiently pleasing to have gained a strong entry into the food-service industry and even into the home.

### Comminuted Meats

Meats can be chopped into very tiny pieces, mixed with water, and heated to denature the proteins. Phosphate, sodium chloride, and other salts may be added to improve the physical characteristics of the meat mixture and increase sensory qualities such as juiciness and texture. Modifications in fat type and amount are emerging to expand the acceptability of these **comminuted meats**, which include hot dogs and sausages.

### Structured Seafood Products

Public interest in nutrition is reflected by increased consumption of fish, a change that has stimulated efforts to provide new types and products in the marketplace. One of the products of fish processing is minced fish meat, which is washed thoroughly to eliminate fat, pigments, and other compounds that would present flavor and storage problems during frozen storage. A preservative of some type, commonly sorbitol or sugar, is added before minced fish is frozen in preparation for its use in structured seafood products. This intermediate seafood product is called **surimi**.

Technically, surimi could contain any type of minced fish. However, pollock is the predominant choice; other types of fish (especially the less popular fish that are caught along with more costly types) are included as available. Preparation of surimi requires deboning of either filleted or headed and gutted fish; filleting (Figure 12.14) results in a higher grade surimi with lighter color and better gel-forming ability.

Mincing of the deboned fish with a drum that has small perforations (1–2 millimeters) produces a particularly high-quality product. The minced fish requires careful, thorough washing, rinsing, straining, and some dehydration to achieve a moisture level of around 82 percent. The last step prior to freezing is incorporation of the preservative or cryoprotectant.

The principal use of surimi for human food has been in fabricating structured seafood products, notably crab and shrimp analogs. As minced fish alone does not have the textural characteristics associated with crab and shrimp, egg white and a starch (the type used depends on the product being made) are added to the surimi to achieve the desired firmness without rubberiness. Each of these two ingredients appears to regulate the influence of the other, with starch promoting rubberiness and egg white interfering with the structural matrix that contributes a rubbery texture to the original surimi. A limited amount of oil (not more than 4 percent) is added to improve the freeze-thaw characteristics of these structured seafood products.
The mixture undergoes fiberization to achieve an end product that rather closely approximates the texture of crabmeat or shrimp. This mixture is extruded as a sheet and heated briefly so that the sheet is elastic and can be folded and molded. After the extruded mixture is in the desired final form, it is heated sufficiently to gelatinize the starch and completely denature the protein without causing excessive toughness and rubberiness. The surface is colored to simulate crab and shrimp products.

Considerable research effort has been directed toward the development of surimi-based structured seafood products, and these products have become an accepted choice by many consumers. The distinct economy of the shrimp and crab analogs and their present level of quality have made them viable fish products.

SOY PROTEIN

Products

Plant proteins have been the subject of a considerable amount of research for many years because of their nutritional similarity to meat proteins. In addition to those who avoid meat for religious reasons, many other consumers have adopted at least some vegetarian protein products because of their concern for animal rights. As the numbers of vegetarians have increased, there has been increasing emphasis in the food industry to meet this demand.

So far, soy protein has proven to be by far the most versatile and economically feasible of the plant proteins that have been studied. At the present time, several soy protein products are available to consumers to add variety in flavor and texture to many main dishes and other recipes (Figure 12.15). Dried soybeans are remarkably high in protein, actually about 34 percent. The blend of essential amino acids is unusually complete for a plant protein, which is an important reason why soy protein is recommended by nutritionists and dietitians as an excellent means of meeting part of the day’s protein needs. Methionine is the limiting essential amino acid in soy protein.
Chapter 12  Meats, Poultry, and Fish

Chapter 12  Meats, Poultry, and Fish

Soybeans undergo several steps in their processing to obtain the products seen in the marketplace. After the beans are hulled, the oil is extracted, and the remaining portion is soy flour, with a protein content of about 50 percent. Additional steps utilizing alkali and acid at various points to alter pH result in a variety of **soy protein concentrates** and **soy protein isolates**, with protein levels ranging from 70 percent in the concentrates to as high as 95 percent in the isolates. The concentrates are important in formulating vegetarian meat alternatives, often in conjunction with cereals; isolates are particularly well suited for use in beverages and energy bars.

From the isolates, texturized soy protein products are made by various processes including the extrusion of cooked soy flour and spinning fibers; the latter is accomplished by forcing the dissolved isolate through a spinnerette and coagulating the resulting product as fibers. The fibers can be fabricated into simulated meat products, sometimes with rather good success. NutriSoy Next™ is a textured extruded meat alternative combining soy and vegetable protein that is suitable for use in a variety of vegetarian products. Imitation bacon bits of textured soy protein are a familiar example. **Textured soy protein (TSP)** is also called **textured vegetable protein (TVP)**.

Although texturized vegetable protein is the form of soy used most frequently, soy flour and soy grits also have some specific uses. **Soy grits** are made by grinding defatted flakes of soy to a distinctly coarse particle size. These are incorporated into some commercial food products to alter textural characteristics of some ground meat products and cereals.

If grinding is continued so that a fairly fine powder is formed from the soy flakes, the product is **soy flour**, and its protein content is 50 percent. For optimal shelf life, defatted soy flour is suggested. This type of flour is used as an ingredient in some bakery products because of its nutritional merits and favorable influence on tenderness and crust color. However, it needs to be used at levels no greater than 3 percent of the weight of wheat flour in some baked products and certainly no higher than about 10 percent in doughnuts. The lack of the structural protein complex (gluten) limits the usefulness of soy flour in batter and dough mixtures, making it necessary that enough wheat flour is incorporated to ensure adequate strength of structure.

A different type of soy product is made by forming a curd from soy milk, a process rather similar to making cheese from animal milks. The result is a bland, slightly spongy

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**Figure 12.15** Dried soybeans are made into a wide array of food products. (Courtesy of Agricultural Research Service.)

**Soy protein concentrate**
Defatted soy product usually containing about 70 percent protein.

**Soy protein isolate**
Defatted, highly concentrated (up to 95 percent) soy protein; used to make many textured soy products.

**Textured soy protein (TSP) or textured vegetable protein (TVP)**
The end product of a series of steps producing fibers from soybeans.

**Soy grits**
Coarsely ground soy flakes.

**Soy flour**
Finely ground soy flakes.
precipitated soy protein food called tofu. Tofu is made in three different forms (Table 12.5) commonly available to provide the texture needed for easy use in a wide variety of recipes. Firm tofu is the most concentrated, dense form and is well suited to recipes that use tofu cubes. Soft tofu has a high enough moisture content to assure easy blending into soups or sauces. Silken tofu, with its custard-like texture, also blends well or can be served with a simple topping. Nutritionally, silken tofu is interesting because it has a fat content providing only 30 percent of the calories, compared with fat calories of 45 percent from firm tofu or 52 percent from soft tofu. Tofu needs to be kept covered with water during refrigerated storage, and the water needs to be changed every day.

Tofu is a common ingredient in many Asian recipes and is included to add variety in texture and flavor, as well as to increase the protein content of the dish. This meat alternative may be used effectively as large, distinct cubes in main dishes, soups, and salads. It also may be pureed so that it blends smoothly with other ingredients in sauces or even in desserts such as cheesecake. Yet another illustration of the versatility of tofu in food preparation is a frozen dessert that is the soybean counterpart of ice cream.

A few types of soy cheeses are available—a mozzarella simulation is one. These products contain approximately 6 g of protein per ounce, part of it caseinate from cow's milk. The isoflavone content from soybeans is 6–7 milligram per 100 g of soy cheese.

Fermented soy products are popular in Asian cuisines. Tempeh is a chewy, cake-like product made by cooking soybeans and then adding a culture to ferment the beans. Natto also is fermented after cooking whole soybeans. Fermentation results in a smelly, viscous (almost cheese-like) product for use in soups or as a spread.

Miso is a pasty condiment made by allowing soybeans, a mold, and salt (often with rice or other grain) to age together for as long as three years. This salty fermented soy product is popular in Japan to season soups, sauces, and other dishes.

### Using Textured Soy Proteins

Although textured soy protein products can be made into meat analogs, a different application as a meat extender has gained reasonable acceptance. By mixing some textured soy protein with ground meats, a given quantity of meat can serve an increased number of people, thus reducing food costs. The amount that can be used has been studied to determine just how much soy can be added successfully. An important contribution made by the added soy protein is improved juiciness in comparison with all-beef patties. However, flavor and texture are influenced negatively when the level of soy protein is close to 20 percent.

The comparatively low cost of soy protein as contrasted with that of beef makes the use of textured soy protein as an extender attractive when beef prices are high. Federal school lunch programs are permitted to extend meat by using up to 25 percent textured soy protein in ground meat mixtures. Many sausages, chicken nuggets and other formed poultry, and ground meat products are made with soy protein isolates and concentrates to enhance juiciness and increase yield.

The water-binding capability of textured soy protein and other soy products enhances juiciness, in part because of water content. However, fat that may be present in a beef patty or meat loaf made with soy protein will be bound by the soy protein and retained in the final product. This retentive characteristic limits the usefulness of TVP as a meat extender; retained fat cannot be removed, which may mean the final product has a higher fat content than if the fat were carefully removed from a 100 percent beef patty or loaf.

<table>
<thead>
<tr>
<th>Table 12.5 Tofu Products and Their Uses</th>
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<tbody>
<tr>
<td>Product</td>
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<tr>
<td>Firm tofu</td>
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<tr>
<td>Soft tofu</td>
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<tr>
<td>Silken tofu</td>
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Tofu
Soybean curd.

Tempeh
Fermented cooked soybean product resembling cake.

Natto
Fermented cooked soybean product useful as a spread or in soups.

Miso
Paste made by fermenting a mold culture with soybeans, salt, and often rice for up to three years.
**Quorn™**

An innovative mycoprotein suitable for making meat analogs was developed in the United Kingdom and marketed with the name Quorn™. Researchers there harvested the hyphae from *Fusarium venenatum*, a fungus growing in a field. Production includes controlled fermentation with glucose as the medium, followed by harvesting of the fibrillar hyphae. The hyphae tubules are mixed with a binding agent. Finally, the mixture is heated and frozen in a patented process that develops a texture similar to that of meat. A rather wide range of entrées can be found in some markets, particularly those catering to vegetarians and others seeking alternative protein sources.

**FOOD FOR THOUGHT**

**Petri Burgers?**

Imagine a burger that started in a petri dish, a product of bioengineering by scientists merging medical research frontiers with food science. Will it ever happen? The answer to that question is far from certain at the present time, but research efforts in laboratories in Australia, Europe, and North America are developing techniques for growing muscle cells into tissues.

Researchers at the University of Western Australia and Harvard University produced a thin monolayer of cells that are nourished in a bioreactor that maintains a sterile environment. These cells then need to be developed into a thicker cluster. Some researchers at the International Institute of Biophysics in the Netherlands have explored developing a scaffold or matrix approach to facilitate development of clusters to give dimension to the cell cluster beyond the monolayer. The ultimate goal of this type of research for medicine is to synthetically produce organs.

Another possible future development could be muscle tissue that could serve as a food source, thus providing a protein source that would eliminate current concerns such as mad cow disease. Far into the future, space travelers may benefit by being able to carry a regenerating meat source without having to solve the problems of transporting animals. It all sounds like science fiction today, but basic research undertaken today may provide answers to people in the future.

**GELATIN**

**Composition**

Gelatin is a stabilizing and gelling agent that has a variety of applications in the food industry as well as at home. Although it must compete with an array of carbohydrate gums in the food industry, this unique protein remains unchallenged in home food preparation. The origin of gelatin is the tropocollagen strands of collagen, a protein in the connective tissue of meat that undergoes a change during heating (see p. XXX).

**Properties**

**Hydration** When gelatin is used in food preparation, the first step is to convert it from a firm, friable substance to one that is soft and pliable. The elongated gelatin molecules have many polar groups exposed, making it possible for water to be bound by hydrogen bonds at many points along each molecule. As water is bound, the gelatin swells noticeably. This can be observed easily by placing a packet (tablespoon) of gelatin in one-fourth cup of water. The remarkable ability of gelatin to bind water and also to trap free water in the interstices between molecules enables a small amount of gelatin to hold a far greater amount of water in a very short period. Evidence of this is the swollen volume of the hydrated gelatin and the lack of water that can be poured off.
The swelling of gelatin when it adsorbs water is influenced by the pH and the presence of salts. Swelling is bimodal in that it is less at its isoelectric point than it is at either a more acidic or a more alkaline pH. For many gelatins, the pH at which hydration is at a maximum is around pH 3.2–3.5 or 9. The effect of different salts on hydration is variable, but salts do promote swelling at the isoelectric point of gelatin. Unfortunately, no specific isoelectric point can be given for gelatin because of its heterogeneous nature and the fact that different production methods influence the pH of the isoelectric point. Usually, the isoelectric point for alkaline-processed gelatins is between 4.75 and 5.2 and that for acid-processed gelatins is between 5.5 and 6.5.

**Sol Formation** Unless gelatin has been hydrated first in cold water, a gelatin sol can be achieved only with considerable difficulty when the hot liquid is added. After hydration in cold water, the swollen gelatin can be dispersed readily in hot water or other hot liquid. Apparently this ability to be dispersed as a sol is aided by the physical dissociation of the gelatin molecules from their closely packed, dehydrated state.

The distancing that occurs between gelatin molecules during hydration in cold water weakens intermolecular association and enables hot water to complete the dissociation, allowing the long gelatin molecules to move freely as the discontinuous phase in the sol. The high temperature facilitates the breaking of weak hydrogen bonds that exist in the hydrated gelatin.

For gelatin to be an acceptable ingredient in any food product, the individual molecules must be dispersed in a very hot liquid. When molecules adhere to each other rather than dispersing, their fibrous and compact nature makes them quite rubbery and tenacious, characteristics that definitely are undesirable in foods. For this reason, hot gelatin sols are stirred until they appear to be absolutely transparent and totally homogeneous. If this state is not reached with a reasonable amount of stirring, it may be necessary to heat the sol longer to provide the energy needed for dissociation of the molecules of gelatin.

**Enzymatic Hydrolysis** Various proteolytic enzymes are able to cleave the long gelatin molecules into shorter polypeptides. This change in molecular length quickly eliminates the usual ability of gelatin to form gels. If ingredients containing enzymes capable of catalyzing this proteolysis are incorporated into gelatin mixtures, a satisfactory gel cannot form. Among the foods containing these enzymes are papaya, which contains papain; pineapple, which contains bromelain; figs, which contains ficin; and kiwi fruit, which contains actinidin. These enzymes lose their catalytic capability if they are heated until denatured, which explains why canned pineapple can be used in gelatin salads whereas frozen and fresh pineapple cannot.

**Gel Formation** Under appropriate conditions, a gelatin sol can convert to a gel as the sol is cooled. The formation of a gelatin gel is only one familiar example of gel formation. In the case of a gelatin gel, the gelatin molecules cross-link to form a continuous network of solid protein to which some water is bound and in whose interstices additional water is trapped as the discontinuous phase.

The formation of a gelatin gel is endothermic and occurs gradually as the energy of the system dissipates. A surface film forms as some of the gelatin molecules cross-link in a comparatively compact configuration. When the interior begins to gel, the molecules of gelatin are organized quite randomly.

There is considerable formation and subsequent disruption of secondary bonds and reformation of new bonds with the molecules in slightly different positions as the gel structure ages. Gradually, a somewhat more organized arrangement evolves in a gelatin gel that has been stored many hours. In other words, a gelatin gel actually is a somewhat dynamic colloidal dispersion and is subject to gradual change, which is evidenced by decreasing tenderness during storage.

Conversion from a gelatin sol to a gel depends on several factors. First, enough gelatin molecules must be present to cross-link through the entire system to form the continuous network. If the concentration is too dilute, the sol will remain in that state. Even when
there is enough gelatin to form a gel, the concentration influences gel formation. As the concentration increases, the rate of gel formation also increases—that is, the gel forms more quickly with an increasing concentration of gelatin.

It is necessary to avoid too high a concentration of gelatin because the concentration influences the texture of the gel formed as well as the rate of its formation. Increasing the concentration of gelatin causes the gel to become increasingly firm and less tender. Too high a concentration is undesirable because of the rubbery consistency that develops. A satisfactory gel often can be formed with a concentration of only 1.5 percent gelatin by weight, but in some other systems, the level of gelatin may need to be about 3 or even 4 percent. An average figure of about 2 percent is appropriate for many applications.

The temperature to which a gelatin sol must be cooled for gelation to occur is influenced by the rate of cooling. The temperature of gelation will be lower if the sol is cooled rapidly by adding ice to the dispersed gelatin or by packing the bowl containing the sol in ice than if the gel is cooled slowly at refrigerator temperature. Despite the fact that the gel sets at a lower temperature when ice is used, the time required for gelation is less than is necessary when cooling occurs in the refrigerator because the temperature drops quickly as the ice melts.

A gelatin sol with a high enough concentration of gelatin can be gelled in about three hours by allowing it to cool at room temperature, a rate that is obviously slower than that occurring in the refrigerator. Even when the gelatin concentration is very high, a gelatin sol must be cooled to at least 35°C (95°F) before a gel can form. The energy of the system is too great to permit the necessary bonding between molecules if the sol is above that temperature, and there is inadequate stability to any bonds that might be able to form.

Stability of the gel is influenced by the rate at which the gel forms. Gelatin gels that are set in the refrigerator require considerable patience because of the long time required for them to set compared with those using ice to cool. They do have the advantage that they are much more resistant to melting back to a fluid sol when they are served on a warm day. This method of gel formation may be appealing if the gelatin gel must be held at room temperature or warmer for a long period, as often is true at buffets or picnics.

Fortunately, for people with severe restrictions on their preparation time, addition of ice cubes to the dispersed gelatin or chilling of the gelatin in a bowl placed in ice water makes a gel that remains sufficiently firm for easy service at most meals if the product is made far enough in advance to allow time for the gel to become stronger by cross-linking during storage.

Use of milk as the dispersing liquid in place of water produces a stronger gelatin gel than does a comparable amount of water. The increased strength may result from the interactions of the gelatin with the milk proteins and salts. This is of particular interest when gelatin is added as a stabilizing agent in ice cream, and it also has application when cream cheese, cottage cheese, and other dairy products are incorporated into a gelatin salad.

To a limited extent, variations in the pH of the gelatin system influence the strength of the gelatin gel formed. Greatest strength is found in systems between pH 5 and 10, but the flavor generally is particularly pleasing at pH 3–3.5, significantly more acidic than the isoelectric point of gelatin. Fortunately, gel strength is adequate at this range.

Sugar frequently is added to temper the acidic taste of tart gelatin mixtures. The effect of sugar on gelation time and gel strength depends on the concentration of sugar. In concentrations up to 0.02–0.03 M, sugar delays gelling. At levels above 0.1 M (68.4 g or about ½ cup per liter), sugar has the opposite effect and actually speeds gelation. This level is less than half the amount of sugar that frequently is added to sweetened and acidified gelatin sols. Therefore, it is reasonable to anticipate that gelatin sols containing sugar ordinarily set more rapidly than they would without the sugar. However, these large amounts of sugar in gelatin do increase the tenderness of the resulting gel.

Gelatin gels are thixotropic—that is, they can revert to a sol when agitated. This reversal is due presumably to the breaking of hydrogen bonds between gelatin molecules in the gel. This is seen when fruit or another ingredient is stirred into a gelatin mixture that has gelled enough to pile; it softens and becomes quite smooth with the agitation necessary to blend the fruit uniformly into the entire mixture.

Gels also can be reversed to sols if the temperature rises sufficiently. The reversibility of gelatin gels to sols and back to gels can be demonstrated repeatedly, for the hydrogen
bonds and other secondary bonds that may be responsible for establishing the gel structure can be broken by providing sufficient energy and re-formed by removing energy, specifically by cooling. Interestingly, the temperature required for gelation to occur is somewhat lower than the temperature required for reversal to form a sol. One of the curious aspects of gelatin is that gelation occurs more rapidly the second time the product is gelled.

Gelatin can be beaten to form a foam if handled properly. The excellent foaming properties of this protein make it possible for gelatin to increase as much as threefold in volume. The optimal time to beat gelatin into a foam is when the dispersed gelatin sol has cooled so that the mixture has the consistency of a thick syrup. The surface tension is low enough so that the gelatin can be spread into extensive thin films surrounding bubbles of air, and the cooled gelatin will congeal quickly to add stability to the cell walls in the foam. This capability of gelatin is used in preparing some stabilized foam desserts and whipped gelatin salads. Beating must be done before the gelatin actually congeals because the gelatin will then be so brittle that it will break into pieces and will not be capable of being spread to form the cell walls needed for foam formation. Fortunately, gelatin can be warmed a bit when this happens so that the problem can be rectified.

Gelatin is used in numerous recipes, most frequently as the background matrix for a congealed salad with various other ingredients added to give variety. In some cases, plain granulated gelatin is used; other recipes utilize pulverized, sweetened gelatin with coloring and flavoring added. Plain gelatin requires hydration with cold water prior to dispersal in a hot liquid. Otherwise, it clumps badly.

The finer consistency of the sweetened gelatin product and the dilution of the gelatin by the sugar enable this type of gelatin to be dispersed directly in a hot liquid without preliminary hydration. Yet another gelatin product is sweetened with a sugar substitute to reduce the calories. This product also does not require preliminary hydration.

**SUMMARY**

Flesh foods are categorized as meat, poultry, or fish; the latter is divided into fish and shellfish (mollusks and crustaceans). These foods contain both muscle and connective tissue. The proteins in muscle consist of enzymes and the abundant myofibrillar proteins. In the presence of ATP, calcium, and magnesium ions, actin and myosin unite to form actomyosin in a reaction that is reversible and is accompanied by contraction and relaxation of muscles (when actin and myosin are released from actomyosin).

Connective tissue also is composed of proteins, including elastin, reticulin, ground substance, and collagen, the most important in meat cookery. Tropocollagen, the basic component of collagen, is made of three fibrous strands. Three strands of tropocollagen, in turn, are twisted together to form long and fibrous strands of collagen. Hydroxyproline and proline, amino acids present in unusual abundance in tropocollagen and collagen, account for the fibrous nature of these proteins. Elastin is the yellow, tough connective tissue that is found to a small extent intramuscularly and also in some large deposits intermuscularly. Ground substance provides the protein matrix in which collagen and elastin are deposited to form connective tissue. Reticulin is another fibrous protein associated with a fatty acid in connective tissue.

Triglycerides containing a variety of fatty acids (particularly palmitic, oleic, and stearic) are the predominant form of lipids in meats. Others are cholesterol, glycolipids, phosphoglycerides, plasmalogens, and sphingomyelin. These various components constitute the fat depots in which they are embedded in a matrix of connective tissue.

Organization of muscle tissue is complex, beginning with thick and thin myofilaments consisting of myosin and actin. Connective tissue, the endomysium, encases the fibers. Several fibers are held together in bundles by more connective tissue, the perimysium. Bundles of these bundles are finally encased in still more connective tissue, the epimysium, to form the completed muscle.

Hemoglobin and myoglobin are the two principal iron-containing pigments in red meats. Myoglobin, in its various forms, is particularly important. In the ferrous (2) form, it is the purple-red color of fresh meat. Exposure to air adds two atoms of oxygen to make...
oxymyoglobin, a bright red pigment. Metmyoglobin, a brownish-red pigment, forms if the iron is oxidized to the ferric (3+) state. Heating causes gradual changes in pigment to the grayish-brown compound, denatured globin hemichrome. With the addition of nitrites, nitric oxide myoglobin forms during curing of meats and undergoes conversion to nitric oxide myochrome when heated, resulting in the stable reddish color of cured meats. Another pigment found in cured meats is nitrosyl-hemochrome. Poultry and fish generally have little pigmentation, although poultry may have some reddish color from hemoglobin, and fish may have some dark muscles colored by myoglobin. Salmon red is the result of astaxanthin, a carotenoid pigment.

Quality of the various meats is judged on the basis of texture, marbling, and overall palatability; yield is based on the amount of muscle in relation to bone and fatty deposits. Meat cuts can be identified on the basis of the size of the cut, color, muscles present, and bone shape.

When heated, muscle fibers shrink a bit lengthwise and lose some of their water-binding capacity. Concurrently, connective tissue (specifically collagen) begins to be converted slowly to gelatin. An acid marinade is of limited benefit in promoting palatability of less tender cuts of meat.

Meat tenderizers are somewhat effective in destroying the sarcolemma surrounding fibers and in hydrolyzing actomyosin, as well as possibly hydrolyzing some of the collagen. The overall effect may be to create a somewhat mushy texture in some areas. This action occurs during the heating of the meat. Mechanical devices can tenderize less tender cuts of meat prior to heating.

Dry heat methods for tender cuts include roasting, broiling, pan broiling, pan frying, deep-fat frying, and microwave cookery. Less tender cuts may be prepared effectively by braising and stewing; fish may be poached. Cooking losses vary with various factors such as temperature and method of heating, as well as final temperature of the meat.

Textured soy protein can be made into meat analogs such as imitation bacon bits and can also be used to extend ground meats. Soy grits and soy flour are used to some extent in the baking industry to enhance the protein content of baked products. However, they can replace only about 3 percent of the wheat flour in most baked products, whereas a substitution of from 20 to 25 percent can be made when textured soy protein is used to extend meat. Other analogs use surimi, a minced fish intermediate product that usually contains pollack and other available fish. Tofu, tempeh, miso, natto, and cheese are other soy products.

Gelatin is the protein derived from collagen. The molecules are somewhat varied but are fibrous as a result of the high content of proline and hydroxyproline. Commercial gelatin usually is obtained by alkaline extraction and finally is dried and marketed as granular or pulverized gelatin. Plain gelatin requires hydration in cold water to disperse and swell. Water is bound and trapped in the interstices between gelatin molecules. When hydrated gelatin is dispersed in hot water, it forms a sol, which on cooling forms a gel. The presence of proteolytic enzymes in a gelatin gel results in liquefaction as the gelatin molecules are cleaved to shorter, more soluble molecules by the enzymes.

A gel forms as the gelatin molecules begin to establish a continuous, solid network by forming hydrogen bonds and other secondary bonds. Water is bound to these molecules and also is trapped within the framework. The strength of the gel depends on the concentration of gelatin, the rate of cooling, the temperature of the gel, the age of the gel, the presence of electrolytes, the pH, and the amount of sugar present. Mechanical agitation causes thixotrophy in gelatin gels. Gelatin gels and sols are reversible, depending on the temperature. When gelatin is just beginning to congeal, it can be beaten into a light foam for use in desserts and salads.

STUDY QUESTIONS

1. What are two important proteins in muscles? What happens to them in muscle contraction?
2. Name and describe four types of proteins in connective tissue.
3. Describe the chemistry of collagen, being sure to discuss its unique amino acid composition.
4. Why is moist heat cookery used to prepare a pot roast?
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5. Describe the chemical changes and the resulting color shifts that occur when myoglobin is subjected to different conditions.

6. Why is cured meat a different color than uncured meat?

7. Why is ammonium hydroxide or citric acid used in curing meats?

8. Describe the changes that occur in meats when heated.

9. What are the effects of extending ground meats with textured soy protein?

10. What is surimi and how is it used?

11. Why is cured meat a different color than uncured meat?

12. Why is ammonium hydroxide or citric acid used in curing meats?

13. Describe the changes that occur in meats when heated.

14. What are the effects of extending ground meats with textured soy protein?

15. What is surimi and how is it used?

16. How does the chemical nature of gelatin influence its physical behavior in food preparation?

17. What factors influence the temperature at which gelatin mixtures form gels?

18. What factors determine the tenderness of a gelatin gel?

19. True or false. Dry heat meat cookery tenderizes meat.

20. True or false. Beef cuts from the loin are best when prepared using a moist heat method.

BIBLIOGRAPHY


