Part III

Proteins in Food

Proteins in Food: An Introduction

8

Introduction

Proteins are the most abundant molecules in cells, making up 50 % or more of their dry weight. Every protein has a unique structure and conformation or shape, which enables it to carry out a specific function in a living cell. Proteins comprise the complex muscle system and the connective tissue network, and they are important as carriers in the blood system. All enzymes are proteins; enzymes are important as catalysts for many reactions (both desirable and undesirable) in foods.

All proteins contain carbon, hydrogen, nitrogen, and oxygen. Most proteins contain sulfur, and some contain additional elements; for example, milk proteins contain phosphorus, and hemoglobin and myoglobin contain iron. Copper and zinc are also constituents of some proteins.

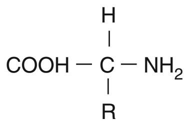
Proteins are made up of amino acids. There are at least 20 different amino acids found in nature, and they have different properties depending on their structure and composition. When combined to form a protein, the result is a unique and complex molecule with a characteristic structure and conformation and a specific function in the plant or animal where it belongs. Small changes, such as a change in pH, or simply heating a food, can cause dramatic changes in protein molecules. Such changes are seen, for example, when cottage cheese is made by adding acid to milk or when scrambled eggs are made by heating and stirring eggs.

Proteins are very important in foods, both nutritionally and as functional ingredients. They play an important role in determining the texture of a food. They are complex molecules, and it is important to have an understanding of the basics of protein structure to understand the behavior of many foods during processing. This chapter covers the basics of amino acid and protein structure. Individual proteins, such as milk, meat, wheat, and egg proteins, are covered in the chapters relating to these specific foods.

Amino Acids

General Structure of Amino Acids

Every ***amino acid*** contains a central carbon atom, to which is attached a carboxyl group (COOH), an amino group (NH_2), a hydrogen atom, and another group or side chain R specific to the particular amino acid. The general formula for an amino acid is



$$\begin{array}{c} \mathrm{H} \\ | \\ \mathrm{COOH}-\mathrm{C}-\mathrm{NH_2} \\ | \\ \mathrm{R} \end{array}$$

Glycine is the simplest amino acid, with the R group being a hydrogen atom. There are more than 20 different amino acids in proteins. Their

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For use with subsequent Protein food chapters.

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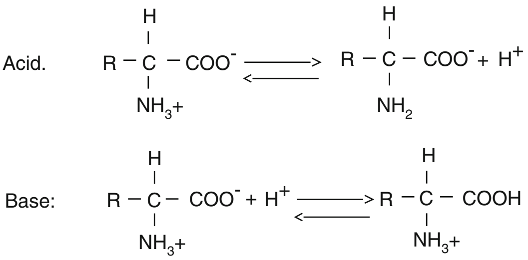
properties depend on the nature of their side chains or R groups.

In a solution at pH 7, all amino acids are ***zwitterions***; that is, the amino group and carboxyl groups are both ionized and exist as COO^- and NH_3^+, respectively. Therefore, amino acids are ***amphoteric*** and can behave as an acid or as a base in water depending on the pH. When acting as an acid or proton donor, the positively charged amino group donates a hydrogen ion, and when acting as a base the negatively charged carboxyl group gains a hydrogen ion, as follows:



Acid.

$$R-\overset{\displaystyle H}{\underset{\displaystyle NH_3+}{C}}-COO^- \rightleftharpoons R-\overset{\displaystyle H}{\underset{\displaystyle NH_2}{C}}-COO^- + H^+$$

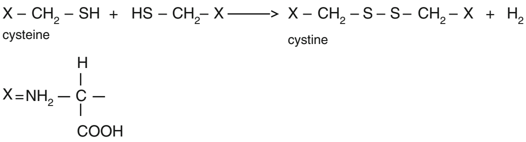
Base:

$$R-\overset{\displaystyle H}{\underset{\displaystyle NH_3+}{C}}-COO^- + H^+ \rightleftharpoons R-\overset{\displaystyle H}{\underset{\displaystyle NH_3+}{C}}-COOH$$

Categories of Amino Acids

Amino acids can be divided into four categories, according to the nature of their side chains, as shown in Fig. 8.1. The first category includes all the amino acids with ***hydrophobic*** or **nonpolar** side chains. The hydrophobic (water-hating) amino acids contain a hydrocarbon side chain. Alanine is the simplest one, having a methyl group (CH_3) as its side chain. Valine and leucine contain longer, branched, hydrocarbon chains. Proline is an important nonpolar amino acid. It contains a bulky five-membered ring, which interrupts ordered protein structure. Methionine is a sulfur-containing nonpolar amino acid. The nonpolar amino acids are able to form hydrophobic interactions in proteins; that is, they associate with each other to avoid association with water.

The second group of amino acids includes those with **polar uncharged** side chains. This group is ***hydrophilic***. Examples of amino acids in this group include serine, glutamine, and cysteine. They either contain a hydroxyl group (OH), an amide group ($CONH_2$), or a thiol group (SH). All polar amino acids can form hydrogen bonds in proteins. Cysteine is unique because it can form ***disulfide bonds*** (—S—S—), as shown below:



$$\underset{\text{cysteine}}{X-CH_2-SH} + HS-CH_2-X \longrightarrow \underset{\text{cystine}}{X-CH_2-S-S-CH_2-X} + H_2$$

$$X=NH_2-\overset{\displaystyle H}{\underset{\displaystyle COOH}{C}}-$$

A disulfide bond is a strong covalent bond, unlike hydrogen bonds, which are weak interactions. Two molecules of cysteine can unite in a protein to form a disulfide bond. A few disulfide bonds in a protein have a significant effect on protein structure, because they are strong bonds. Proteins containing disulfide bonds are usually relatively heat stable, and more resistant to unfolding than other proteins. The presence of cysteine in a protein therefore tends to have a significant effect on protein conformation.

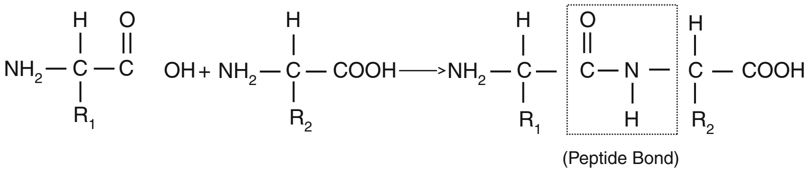
The third and fourth categories of amino acids include the charged amino acids. The **positively charged (basic)** amino acids include lysine, arginine, and histidine. These are positively charged at pH 7 because they contain an extra amino group. When a basic amino acid is part of a protein, this extra amino group is free (in other words, not involved in a peptide bond) and, depending on the pH, may be positively charged.

The negatively charged (acidic) amino acids include aspartic acid and glutamic acid. These are negatively charged at pH 7 because they both contain an extra carboxyl group. When an acidic amino acid is contained within a protein, the extra carboxyl group is free and may be charged, depending on the pH.

Oppositely charged groups are able to form ionic interactions with each other. In proteins, acidic and basic amino acid side chains may interact with each other, forming ionic bonds or salt bridges.

Protein Structure and Conformation

All proteins are made up of many amino acids, joined by ***peptide bonds*** as shown below:



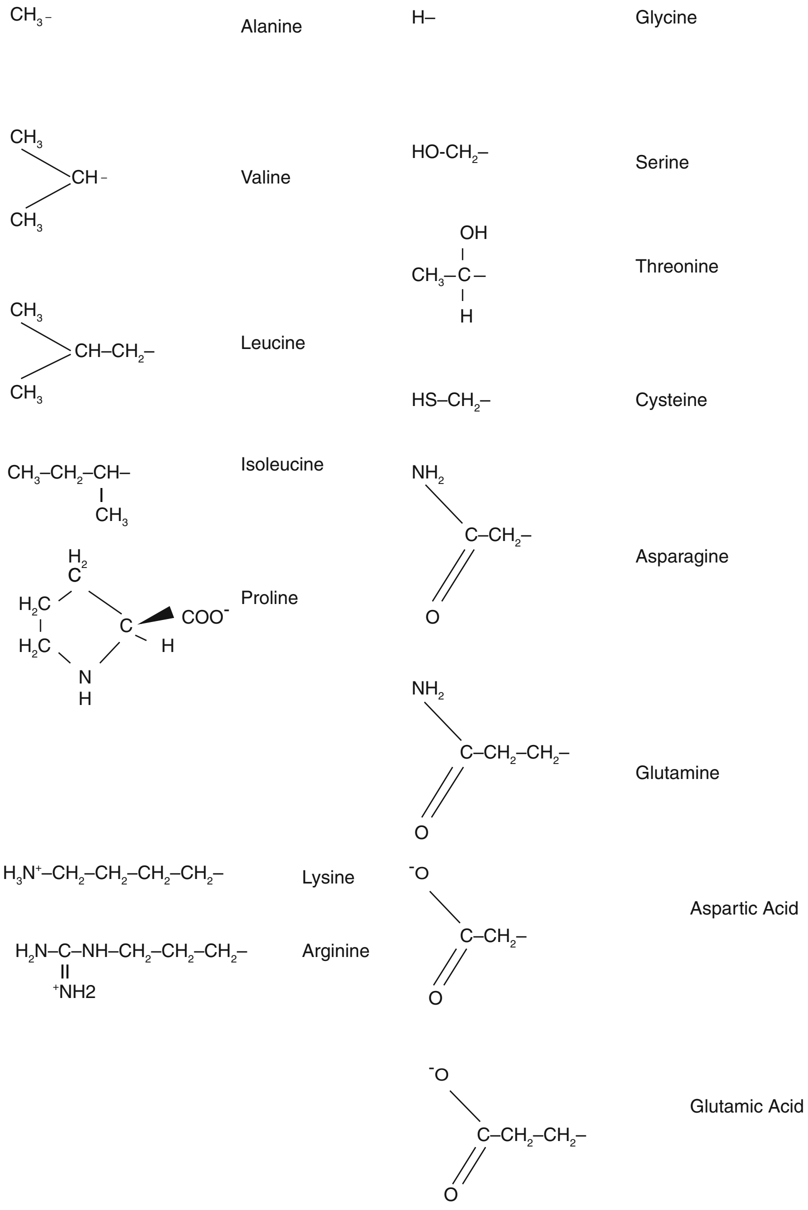
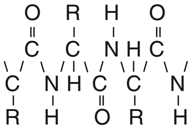


Fig. 8.1 Examples of amino acids classified according to the nature of their R groups (only the side groups are shown)

Peptide bonds are strong bonds and are not easily disrupted. A ***dipeptide*** contains two amino acids joined by a peptide bond. A ***polypeptide*** contains several amino acids joined by peptide bonds. Proteins are usually much larger molecules, containing several hundred amino acids. They can be hydrolyzed, yielding smaller polypeptides, by enzymes or by acid digestion.

The sequence of amino acids joined by peptide bonds forms the backbone of a protein, as shown below:



- The protein backbone consists of repeating N—C—C units.
- The amino acid side chains (R groups) project alternately from either side of the protein chain.
- The nature of the R groups determines the structure or ***conformation*** of the chain. (In other words, the shape the protein assumes in space.)

Each protein has a complex and unique conformation, which is determined by the specific amino acids and the sequence in which they occur along the chain. To understand the function of proteins in food systems and the changes that occur in proteins during processing, it is important to understand the basics of protein structure. Proteins are described as having four types of structure—primary, secondary, tertiary, and quaternary structure—and these build on each other. The primary structure determines the secondary structure and so on. The different types of protein structures are outlined below.

Primary Structure

The primary structure (***protein primary structure***) of a protein is the specific sequence of amino acids joined by peptide bonds along the protein chain. This is the simplest way of looking at protein structure. In reality, proteins do not exist simply as straight chains. However, it is the specific sequence of amino acids that determines the form or shape that a protein assumes in space. Therefore, it is essential to know the primary structure if a more detailed understanding of the structure and function of a particular protein is desired.

Secondary Structure

The secondary structure (***protein secondary structure***) of a protein refers to the three-dimensional organization of segments of the polypeptide chain. Important secondary structures include the following:

- Alpha helix—ordered structure
- Beta-pleated sheet—ordered structure
- Random coil—disordered structure

The ***alpha (α) helix*** is a corkscrew structure, with 3.6 amino acids per turn. It is shown in Fig. 8.2. It is stabilized by intrachain hydrogen bonds; that is, the hydrogen bonds occur within a single protein chain, rather than between adjacent chains. Hydrogen bonds occur between each turn of the helix. The oxygen and hydrogen atoms that comprise the peptide bonds are involved in hydrogen bond formation. The α-helix is a stable, organized structure. It cannot be formed if proline is present, because the bulky five-membered ring prevents formation of the helix.

The ***beta (β)-pleated sheet*** is a more extended conformation than the α-helix. It can be thought of as a zigzag structure rather than a corkscrew. It is shown in Fig. 8.3. The stretched protein chains combine to form β-pleated sheets. These sheets are linked together by interchain hydrogen bonds. (Interchain hydrogen bonds occur between adjacent sections of the protein chains rather than within an individual chain.) Again, the hydrogen and oxygen atoms that form the peptide bonds are involved in hydrogen bond

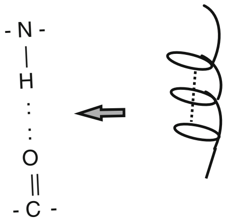


Fig. 8.2 Schematic three-dimensional structure of an α-helix

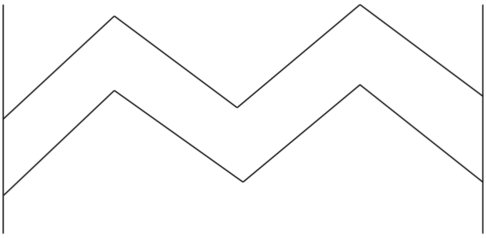


Fig. 8.3 Schematic three-dimensional structure of β-pleated sheets

formation. Like the α-helix, the β-pleated sheet is also an ordered structure.

The ***random coil*** is a secondary structure with no regular or ordered pattern along the polypeptide chain. This is a much more flexible structure than either the α-helix or β-pleated sheet. It is formed when amino acid side chains prevent formation of the α-helix or β-sheet. This may occur if proline is present or if there are highly charged regions within the protein.

A protein may contain regions of α-helix, β-sheet, and random coil at different places along the chain. How much of each type of secondary structure it contains depends on the sequence of amino acids or, in other words, on the primary structure of the protein.

Tertiary Structure

The ***tertiary structure*** of a protein refers to the three-dimensional organization of the complete protein chain. In other words, it refers to the spatial arrangement of a protein chain that contains regions of α-helix, β-sheet, and random coil. So, this structure is really an overview of a protein chain, rather than a detailed look at a small section of it. Again, the tertiary structure is built on the secondary structure of a specific protein.

There are two types of protein tertiary structure:
- Fibrous proteins
- Globular proteins

Fibrous proteins include structural proteins such as collagen (connective tissue protein), or actin and myosin, which are the proteins that are responsible for muscle contraction. The protein chains are extended, forming rods or fibers. Proteins with a fibrous tertiary structure contain a large amount of ordered secondary structure (either α-helix or β-sheet).

Globular proteins are compact molecules and are spherical or elliptical in shape, as their name suggests. These include transport proteins, such as myoglobin, which carry oxygen to the muscle. The whey proteins and the caseins, both of which are milk proteins, are also globular proteins. Globular tertiary structure is favored by proteins with a large number of hydrophobic amino acids. These orient toward the center of the molecule and interact with each other by hydrophobic interactions. Hydrophilic amino acids orient toward the outside of the molecule and interact with other molecules; for example, they may form hydrogen bonds with water. The orientation of the hydrophobic amino acids toward the center of the molecule produces the compact globular shape that is characteristic of globular proteins.

Quaternary Structure

Protein quaternary structure, or the quaternary protein structure, involves the noncovalent association of protein chains. The protein chains may or may not be identical. Examples of quaternary structure include the actomyosin system of muscles and the casein micelles of milk. For more information on these structures, the reader is referred to the chapters on meat and milk, respectively.

Interactions Involved in Protein Structure and Conformation

Protein primary structure involves only peptide bonds, which link the amino acids together in a specific and unique sequence. Secondary and tertiary structures may be stabilized by hydrogen bonds, disulfide bonds, hydrophobic interactions, and ionic interactions. ***Steric*** or spatial effects are also important in determining protein conformation. The space that a protein molecule occupies is determined partially by the size and shape of the individual amino acids along the protein chain. For example, bulky side chains such as proline prevent formation of the α-helix and favor random coil formation. This prevents the protein from assuming certain arrangements in space.

Quaternary structures are stabilized by the same interactions, with the exception of disulfide bonds. As has already been mentioned, disulfide bonds are strong, covalent bonds, and so the presence of only a few disulfide bonds will have a dramatic effect on protein conformation and stability. Hydrogen bonds, on the other hand, are weak bonds, yet they are important because there are so many of them.

Each protein takes on a unique native conformation in space, which can almost be considered as a “fingerprint.” As has already been mentioned, the exact folding of the protein into its natural conformation is governed by the amino acids that are present in the protein and the bonds that the side chains are able to form in a protein. The amino acid sequence is also important, as the location of the amino acids along the chain determines which types of bonds will be formed and where, and thus determines how much α-helix, β-sheet, or random coil will be present in a protein. This, in turn, determines the tertiary and quaternary structure of a protein, all of which combine to define its native conformation. Knowledge of protein conformation and stability is essential to understanding the effects of processing on food proteins.

Reactions and Properties of Proteins

Amphoteric

Like amino acids, proteins are ***amphoteric*** (being able to act as an acid or a base) depending on the pH. This enables them to resist small changes in pH. Such molecules are said to have buffering capacity.

Isoelectric Point

The ***isoelectric point*** of a protein is the pH at which the protein is electrically neutral (it is denoted by pI). At this pH, the global or overall charge on the protein is 0. This does not mean that the protein contains no charged groups. It means that the number of positive charges on the protein is equal to the number of negative charges. At the isoelectric point, the protein molecules usually precipitate because they do not carry a net charge. (Molecules that carry a like charge repel each other, and thus form a stable dispersion in water. Removal of the charge removes the repulsive force and allows the molecules to interact with each other and precipitate, in most cases.)

The pH of the isoelectric point differs for each protein. It depends on the ratio of free ionized carboxyl groups to free ionized amino groups in the protein.

The isoelectric point is important in food processing. For example, cottage cheese is made by adding lactic acid to milk to bring the pH to the isoelectric point of the major milk proteins (the caseins). The proteins precipitate at this pH, forming curds. These are separated from the rest of the milk and may be pressed and/or mildly salted before being packaged as cottage cheese.

Water-Binding Capacity

Water molecules can bind to the backbone and to polar and charged side chains of a protein. Depending on the nature of their side chains, proteins may bind varying amounts of water—they have a ***water-binding capacity***. Proteins with many charged and polar groups bind water readily, whereas proteins with many hydrophobic groups do not bind much water. As proteins get closer to their isoelectric point, they tend to bind less water, because reduced charge on the protein molecules results in reduced affinity for water molecules.

The presence of bound water helps to maintain the stability of protein dispersion. This is due to the fact that the bound water molecules shield the protein molecules from each other. Therefore, they do not associate with each other or precipitate as readily, and so the dispersion tends to be more stable.

Salting-in and Salting-out

Some proteins cannot be dispersed in pure water yet are readily dispersed in dilute salt solutions. When a salt solution increases the dispersibility of a protein, this is termed "***salting-in***." It occurs because charged groups on a protein bind the anions and cations of the salt solution more strongly than water. The ions, in turn, bind water; thus, the protein is dispersed in water more easily.

Salting-in is important in food processing. For example, brine may be injected into ham to increase the dispersibility of the proteins. This has the effect of increasing their water-binding capacity, and so the ham is moister and its weight is increased. The same is true for poultry to which polyphosphates are added.

Salting-out occurs at high salt concentrations, when salts compete with the protein for water. The result is that there is insufficient water available to bind to the protein, and so the protein precipitates. This is not normally a problem in food processing. However, it may be a contributing factor to the deterioration of food quality during freezing of foods; during the freezing process, water is effectively removed as ice crystals, and so the concentration of liquid water decreases and the solute concentration increases dramatically. This is discussed in Chap. 17.

Denaturation

Denaturation is the change in the secondary, tertiary, and/or quaternary structure of a protein. There is no change in the primary structure. In other words, denaturation does not involve breaking of peptide bonds. The protein unfolds, yet there is no change in its amino acid sequence.

Denaturation may occur as a result of the following:

- Heat
- pH change
- Ionic strength change (changes in salt concentration)
- Freezing
- Surface changes (occurring while beating egg whites)

Any of these factors may cause breaking of hydrogen bonds and salt bridges. As a result, the protein unfolds and side chains that were buried in the center of the molecule become exposed. They are then available to react with other chemical groups and, in most cases, the denatured protein precipitates. This reaction is usually irreversible; it is not possible to regain the original conformation of the denatured protein.

The changes that produce denaturation are usually mild changes. In other words, mild heat treatment, such as pasteurization or blanching, or small changes in pH are sufficient to change the conformation of a protein.

Denatured proteins normally lose their functional properties; that is, they are unable to perform their normal function in a food. Enzymes are inactivated and so the reactions that they catalyzed can no longer take place. This has important implications in food processing.

Denaturation may be desirable and can be deliberately brought about by food processing. Examples of desirable denaturation include heating beaten egg white foams to form meringues, adding acid to milk to form cottage cheese, or inactivating enzymes by heat, as occurs when vegetables are blanched before freezing.

Blanching is a mild heat treatment that denatures and inactivates enzymes that would cause rancidity or discoloration during frozen storage.

Sometimes denaturation is undesirable. For example, frozen egg yolks are lumpy and unacceptable when thawed because the lipoproteins denature and aggregate. Overheating of foods can also cause unwanted denaturation. Food processors must be careful to utilize processing methods that do not cause unnecessary deterioration of food quality due to protein denaturation.

Hydrolysis of Peptides and Proteins

Hydrolysis of proteins involves breaking peptide bonds to form smaller peptide chains. This can be achieved by acid digestion, using concentrated acid. This may be appropriate in protein research, but it is not an option in food processing. Hydrolysis is also catalyzed by ***proteolytic*** enzymes. Examples of such enzymes used in foods include ficin, papain, and bromelain, which are used as meat tenderizers. They hydrolyze muscle protein or connective tissue, making meat more tender. It is important to control the duration of time that they are in contact with the meat so that too much hydrolysis does not occur. Too much hydrolysis would make the texture of the meat soft and “mushy” (see Chap. 9).

Another example of a proteolytic enzyme is rennet, which is used to make cheese (see Chap. 11). This enzyme is very specific in its action, hydrolyzing a specific peptide bond in the milk protein. The result of this hydrolysis reaction is aggregation of the milk proteins to form curds, which can then be processed into cheese. (This enzyme continues to act as a proteolytic agent during cheese aging in conjunction with natural enzymes from milk and the starter cultures. Their combined action results in flavor and texture development in aged cheeses.)

Maillard Browning

Maillard browning is the reaction that is responsible for the brown color of baked products. A free carbonyl group of a reducing sugar reacts with a free amino group on a protein when heated, and the result is a brown color. The reaction is highly complex and has a significant effect on the flavor of foods as well as the color. It is known as nonenzymatic browning, because the reaction is not catalyzed by an enzyme. (Maillard browning must be distinguished from enzymatic browning, which is the discoloration of damaged fruits or vegetables and is catalyzed by an enzyme such as phenol oxidase; enzymatic browning is discussed in Chap. 7.)

The Maillard Reaction is favored by the following:

- High sugar content
- High protein concentration
- High temperatures
- High pH
- Low water content

Maillard browning is responsible for the discoloration of food products such as powdered milk and powdered egg. Before drying, eggs are usually “desugared” enzymatically to remove glucose and prevent Maillard browning (see Chap. 10).

The reaction causes loss of the amino acids lysine, arginine, tryptophan, and histidine, as these are the amino acids with free amino groups that are able to react with reducing sugars. With the exception of arginine, these are essential amino acids. (The body cannot make them, and so they must be included in the diet.) Therefore, it is important to retard the Maillard Reaction, particularly in susceptible food products (such as food supplies sent to underdeveloped countries) in which the nutritional quality of the protein is very important.

Enzymes

All enzymes are proteins. Enzymes are important in foods, because they catalyze various reactions that affect color, flavor, or texture, and hence quality of foods. Some of these reactions may be desirable, whereas others are undesirable, and produce unwanted discoloration or off-flavors in foods.

Each enzyme has a unique structure or conformation, which enables it to attach to its specific substrate and catalyze the reaction. When the reaction is complete, the enzyme is released to act as a catalyst again. All enzymes have an optimal temperature and pH range, within which the reaction will proceed most rapidly. Heat or changes in pH denature the enzymes, making it difficult or impossible for them to attach to their respective substrates, and thus inactivating them.

If an enzymatic reaction is required in food processing, it is important to ensure that the optimal pH and temperature range for that enzyme is achieved. Outside the optimal range, the reaction will proceed more slowly, if at all. Heat treatment must therefore be avoided. If this is not possible, the enzyme must be added after heat treatment and subsequent cooling of the food.

On the other hand, if enzyme action is undesirable, the enzymes must be inactivated. This is usually achieved by heat treatment, although it may also be accomplished by adding acid to change the pH.

Examples of desirable enzymatic reactions include the clotting of milk by *rennet*, which is the first step in making cheese (Chap. 11). Ripening of cheese during storage is also due to enzyme activity. Ripening of fruit is also due to enzyme action (Chap. 7). Other desirable enzymatic reactions include tenderizing of meat by proteolytic enzymes such as *papain*, *bromelain*, and *ficin* (Chap. 9). These enzymes are obtained from papaya, pineapple, and figs, respectively.

As was mentioned earlier, these enzymes catalyze hydrolysis of peptide bonds in proteins. They are added to the meat and allowed to work for a period of time. The reaction must be controlled, to prevent too much breakdown of the proteins. The optimum temperature for these enzymes occurs during the early cooking stages. (Hydrolysis proceeds very slowly at refrigeration temperatures.) As meat is cooked, the enzymes promote hydrolysis. However, as the internal temperature continues to rise, the enzymes are inactivated and the reaction is stopped.

Although useful as meat tenderizers, proteolytic enzymes may be undesirable in other circumstances. For example, if a gelatin salad is made with raw pineapple, the jelly may not set, due to action of *bromelain*, which is contained in pineapple. This can be prevented by heating the pineapple to inactivate the enzyme before making the gelatin salad.

Additional examples of unwanted enzymatic reactions include enzymatic browning, which occurs when fruits and vegetables are damaged, due to the action of *polyphenol oxidase*, and produces undesirable discoloration (Chap. 7). Development of off-flavors in fats and fat-containing foods may also be a problem in some circumstances, and this may be caused by *lipase* or *lipoxygenase* (Chap. 12).

Enzymes are inactivated in fruits and vegetables prior to freezing by a mild heat process known as blanching (Chap. 17). The fruits or vegetables are placed in boiling water for a short time, in order to inactivate the enzymes that would cause discoloration or development of off-flavors during frozen storage.

CULINARY ALERT! Do not add fresh pineapple, papaya, kiwi, or other fruits containing proteolytic enzymes to a gelatin gel, or it will not set! Canned fruit of these fruit varieties is not generally available yet it yields better results than fresh.

Functional Roles of Proteins in Foods

Proteins have many useful ***functional properties*** in foods. A functional property is a characteristic of the protein that enables it to perform a specific role, or function, in a food. For example, a protein with the ability to form a gel may be used in a food with the specific intention of forming a gel, as in use of gelatin to make jelly.

Functional properties or roles of proteins in foods include solubility and nutritional value. They may also be used as thickening, binding, or gelling agents, and as emulsifiers or foaming agents.

The functional properties of a specific protein depend on its amino acid composition and sequence since these determine the conformation and properties of the protein.

Although no single protein exhibits all the functional properties, most proteins may perform several different functions in foods, depending on the processing conditions. Some proteins are well known for specific functional properties in foods.

Whey protein is an example of a protein that is used for its *solubility* (Chap. 11). Whey is soluble at acid pH, because it is relatively hydrophilic and able to bind a lot of water, and so, unlike many proteins, it does not precipitate at its isoelectric point. Because of its solubility, whey protein is used to fortify acidic beverages such as sports drinks. Whey protein may also be used as a *nutritional fortifier* in other products including baked goods.

Egg proteins are used as *thickening* or *binding* agents in many food products (Chap. 10). Meat proteins are also good binding agents.

Gelatin and egg white proteins are examples of *gelling* agents (Chap. 10). When egg whites are heated, they form a firm gel as can be seen in a boiled egg. Gelatin is used to make jelly and other congealed products. Gelatin gels are formed when the protein molecules form a three-dimensional network due to association by hydrogen bonds. Gelatin gels can be melted by heating, and reformed on cooling. Egg white gels, on the other hand, are formed due to association by hydrophobic interactions and disulfide bonds, and they do not melt on heating. The proteins of gluten are another example of proteins that are able to associate to form a three-dimensional network. The gluten network is formed during kneading of bread dough, and is responsible for the texture and volume of a loaf of bread. Soy protein may also be used to form food gels.

This "structure-forming protein found in wheat, barley, rye and triticale is also used as a food additive for stabilizing or thickening foods. Yet because an estimated 1 in every 133 people is afflicted with celiac disease, an autoimmune condition in which gluten damages the lining of the small intestine when ingested, food manufacturers are continually looking for ways to remove gluten from some foods, while maintaining product appeal." (Grain Processing Corp 2012) (Diarrhea, constipation, migrains, weight loss, and more may be symptoms that occur.)

Many proteins are used as either *emulsifiers* or *foaming agents*, as discussed in Chap. 13. Proteins are ***amphiphilic***, containing both hydrophobic and hydrophilic sections in the same molecule. This allows them to exist at an interface between oil and water, or between air and water, rather than in either bulk phase. They are able to adsorb at an interface and associate to form a stable film, thus stabilizing emulsions or foams. Egg white proteins are the best foaming agents, whereas egg yolk proteins are the best emulsifying agents. The caseins of milk are also excellent emulsifiers.

Proteins are used in many foods to control texture, due to their ability to thicken, gel, or emulsify. Such food products must be processed, handled, and stored with care, to ensure that the proteins retain their functional properties. Some protein denaturation is usually necessary to form an emulsion, a foam, or a gel. However, too much denaturation due to incorrect processing conditions or poor handling and storage may result in undesirable textural changes (such as breaking of emulsions, loss of foam volume, or syneresis in gels) and must be avoided.

Conjugated Proteins

Conjugated proteins are also known as heteroproteins. They are proteins that contain a prosthetic group that may be an organic or an inorganic component. Examples of conjugated proteins include the following:

- Phosphoproteins—for example, casein (milk protein); phosphate groups are esterified to serine residues.
- Glycoproteins—for example, κ-casein; a carbohydrate or sugar is attached to the protein.
- Lipoproteins—for example, lipovitellin, in egg yolk; a lipid is attached to the protein.
- Hemoproteins—for example, hemoglobin and myoglobin; iron is complexed with the protein.

Protein Quality

Press Release on New Protein Quality Measurement FAO proposes new protein quality measurement.

The Food and Agriculture Organization of United Nations (FAO) has released a report recommending a new, advanced method for assessing the quality of dietary proteins. The report, "Dietary protein quality evaluation in human nutrition," recommends that the Digestible Indispensable Amino Acid Score (DIAAS) replace the Protein Digestibility Corrected Amino Acid Score (PDCAAS) as the preferred method of measuring protein quality.

The report recommends that more data be developed to support full implementation, but in the interim, protein quality should be calculated using DIAAS values derived from fecal crude protein digestibility data. Under the current PDCAAS method, values are "truncated" to a maximum score of 1.00, even if scores derived are higher.

Protein is vital to support the health and well-being of human populations. However, not all proteins are alike as they vary according to their origin (animal, vegetable), their individual amino acid composition and their level of amino acid bioactivity. "High quality proteins" are those that are readily digestible and contain the dietary essential amino acids in quantities that correspond to human requirements.

"Over the next 40 years, three billion people will be added to today's global population of 6.6 billion. Creating a sustainable diet to meet their nutritive needs is an extraordinary challenge that we won't be able to meet unless we have accurate information to evaluate a food's profile and its ability to deliver nutrition," said Paul Moughan, Co-director of the Riddet Institute, who chaired the FAO Expert Consultation.

"The recommendation of the DIAAS method is a dramatic change that will finally provide an accurate measure of the amounts of amino acids absorbed by the body and an individual protein source's contribution to a human's amino acid and nitrogen requirements. This will be an important piece of information for decision makers assessing which foods should be part of a sustainable diet for our growing global population."

Using the DIAAS method, researchers are now able to differentiate protein sources by their ability to supply amino acids for use by the body. For example, the DIAAS method was able to demonstrate the higher bioavailability of dairy proteins when compared to plant-based protein sources. Data in the FAO report showed whole milk powder to have a DIAAS score of 1.22, higher than the DIAAS score of 0.64 for peas and 0.40 for wheat.

DIAAS determines amino acid digestibility, at the end of the small intestine, providing a more accurate measure of the amounts of amino acids absorbed by the body and the protein's contribution to human amino acid and nitrogen requirements. PDCAAS is based on an estimate of crude protein digestibility determined over the total digestive tract, and values stated using this method generally overestimate the amount of amino acids absorbed. Some food products may claim high protein content, but since the small intestine does not absorb all amino acids the same, they are not providing the same contribution to a human's nutritional requirements.

Site: http://www.fao.org/ag/humannutrition/35978-02317b979a686a57aa4593304ffc17f06.pdf—2011

This FAO recommendation "overcomes some of the criticisms of the PDCAAS method, such as considering high-quality proteins, antinutritional factors, amino acid bioavailability and the effect of limiting amino acid." (Kuntz 2013)

Nutrition: See More in Specific Food Commodity Chapters

Nutrition comes into play with new product introductions—both original products and reformulations. "… nearly every fat has been implicated in some sort of dietary brouhaha. Carbohydrates, well, steer clear of sugars and starches, and be wary of fibers that might cause digestive upset. Water seems safe—for now.

And then there's protein … . Protein is a key factor in satiety, so it can help battle the bulge. … one of the strongest nutritional trends for 2013 and beyond. And … not just by adding high-protein ingredients like meat, eggs or beans, but purified sources, like dairy proteins, and vegetable proteins, including soy, canola and even the dreaded gluten." (Kuntz 2013)

What Foods Are in the Protein Foods Group?

All foods made from meat, poultry, seafood, beans and peas, eggs, processed soy products, nuts, and seeds are considered part of the Protein Foods Group. Beans and peas are also part of the Vegetable Group.

Vegetarian Choices in the Protein Foods Group

Vegetarians get enough protein from this group as long as the variety and amounts of foods selected are adequate. Protein sources from the Protein Foods Group for vegetarians include eggs (for ovo-vegetarians), beans and peas, nuts, nut butters, and soy products (tofu, tempeh, veggie burgers).

Choosemyplate.gov

Since the Great Depression adequate protein intake has not been a concern for most Americans, as meat, poultry and other forms of animal protein are readily available and even typically, overconsumed. (Berry 2012)

Conclusion

Proteins are complex molecules that are widely distributed in all foodstuffs. It is important to understand their conformation and reactions in order to know how they will behave during food processing and to understand how to maximize their functional properties. This is especially true of protein-rich foods, where the quality of the final product depends to a large extent on the treatment of the protein during processing and handling. This chapter has focused on general properties of food proteins. More details of the composition and functional properties of some specific food proteins are given in the ensuing chapters.

Notes

10 tips
Nutrition Education Series

with protein foods, variety is key

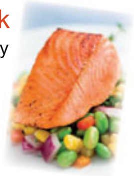
10 tips for choosing protein

Protein foods include both animal (meat, poultry, seafood, and eggs) and plant (beans, peas, soy products, nuts, and seeds) sources. We all need protein—but most Americans eat enough, and some eat more than they need. How much is enough? Most people, ages 9 and older, should eat 5 to 7 ounces* of protein foods each day.

1 vary your protein food choices

Eat a variety of foods from the Protein Foods Group each week. Experiment with main dishes made with beans or peas, nuts, soy, and seafood.

2 choose seafood twice a week



Eat seafood in place of meat or poultry twice a week. Select a variety of seafood—include some that are higher in oils and low in mercury, such as salmon, trout, and herring.

3 make meat and poultry lean or low fat

Choose lean or low-fat cuts of meat like round or sirloin and ground beef that is at least 90% lean. Trim or drain fat from meat and remove poultry skin.

4 have an egg

One egg a day, on average, doesn't increase risk for heart disease, so make eggs part of your weekly choices. Only the egg yolk contains cholesterol and saturated fat, so have as many egg whites as you want.

5 eat plant protein foods more often

Try beans and peas (kidney, pinto, black, or white beans; split peas; chickpeas; hummus), soy products (tofu, tempeh, veggie burgers), nuts, and seeds. They are naturally low in saturated fat and high in fiber.

6 nuts and seeds

Choose unsalted nuts or seeds as a snack, on salads, or in main dishes to replace meat or poultry. Nuts and seeds are a concentrated source of calories, so eat small portions to keep calories in check.

7 keep it tasty and healthy

Try grilling, broiling, roasting, or baking—they don't add extra fat. Some lean meats need slow, moist cooking to be tender—try a slow cooker for them. Avoid breading meat or poultry, which adds calories.

8 make a healthy sandwich

Choose turkey, roast beef, canned tuna or salmon, or peanut butter for sandwiches. Many deli meats, such as regular bologna or salami, are high in fat and sodium—make them occasional treats only.

9 think small when it comes to meat portions

Get the flavor you crave but in a smaller portion. Make or order a smaller burger or a "petite" size steak.

10 check the sodium

Check the Nutrition Facts label to limit sodium. Salt is added to many canned foods—including beans and meats. Many processed meats—such as ham, sausage, and hot dogs—are high in sodium. Some fresh chicken, turkey, and pork are brined in a salt solution for flavor and tenderness.

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* What counts as an ounce of protein foods? 1 ounce lean meat, poultry, or seafood; 1 egg; ¼ cup cooked beans or peas; ½ ounce nuts or seeds; or 1 tablespoon peanut butter.

USDA United States Department of Agriculture
Center for Nutrition Policy and Promotion

Go to www.ChooseMyPlate.gov for more information.

DG TipSheet No. 6
June 2011
USDA is an equal opportunity provider and employer.

CULINARY ALERT!

Glossary

Amino acid Building block of proteins; contains an amino group, a carboxyl group, a hydrogen, and a side chain, all attached to a central carbon atom.

Amphiphilic A molecule that contains both hydrophobic and hydrophilic sections.

Amphoteric Capable of functioning as either an acid or as a base depending on the pH of the medium.

Alpha helix Ordered protein secondary structure: corkscrew shape, stabilized by intrachain hydrogen bonds.

Beta-pleated sheet Ordered protein secondary structure; zigzag shape, stabilized by interchain hydrogen bonds.

Conformation The specific folding and shape that a protein assumes in space.

Denaturation Changes in the conformation (secondary, tertiary, or quaternary structure) of a protein caused by changes in temperature, pH, or ionic strength, or by surface changes.

Dipeptide Two amino acids joined by a peptide bond.

Disulfide bond Strong covalent bond formed by the reaction of two thiol (SH) groups.

Functional property Characteristic of the molecule that enables it to perform a specific role in a food. Examples of functional properties of proteins include solubility, thickening, binding, gelation, foaming, and emulsifying capacity.

Hydrolysis Breaking of one or more peptide bonds in a protein to form smaller polypeptide chains.

Hydrophilic Water-loving; characteristic of polar and charged groups.

Hydrophobic Water-hating; characteristic of nonpolar groups.

Isoelectric point pI; the pH at which the overall charge on a protein is zero; the number of positive charges is equal to the number of negative charges; the protein is most susceptible to denaturation and precipitation at this pH.

Maillard browning The free carbonyl group of a reducing sugar and the free amino group of a protein react to form a brown color; complex nonenzymatic reaction that is favored by high temperatures.

Peptide bond Bond formed by the reaction of the amino group of one amino acid and the carboxyl group of another.

Polypeptide Several amino acids joined together by peptide bonds.

Protein primary structure Specific sequence of amino acids along the protein chain, joined by peptide bonds; the covalently bonded protein backbone.

Protein quaternary structure The noncovalent association of protein chains to form a discrete unit.

Protein secondary structure Three-dimensional arrangement of sections of the protein chain; secondary structures include the α-helix, β-pleated sheet, and random coil.

Protein tertiary structure Three-dimensional arrangement of the whole protein chain; the shape that a protein chain assumes in space; includes fibrous and globular structures.

Proteolytic Breaks down or hydrolyzes proteins.

Random coil A protein secondary structure that exhibits no regular, ordered pattern.

Salting-in Addition of a dilute salt solution to improve the dispersibility of a protein.

Salting-out Addition of a concentrated salt solution to precipitate a protein.

Steric effects Effects caused by the size and shape of the amino acids comprising the protein chain; spatial effects; for example, bulky amino acids can prevent a protein from folding upon itself in certain ways.

Water-binding capacity The ability of a protein to bind water; this ability depends on the number of charged and polar groups along the protein chain.

Zwitterion Contains a positively charged group and a negatively charged group within the molecule.

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9

Meat, Poultry, Fish, and Dry Beans

Introduction

Meat is the edible portion of mammals—the flesh of animals used for food. "Meat" may include rabbit, venison, and other game, as well as the *nonmammals* poultry and fish. The flesh from various animals may be used as food throughout the world.

Red meat is the meat from mammals including beef and veal, lamb, mutton, and pork. White meat refers to meat from poultry. Addressing the question of pork as a white meat, it is determined that its myoglobin content is lower than beef, and yet significantly higher than chicken or turkey white meat. The USDA treats pork as a red meat. In 1987, the US National Pork Board began a successful advertising campaign stating that pork was "the other white meat." This was intended to give the perception that, similar to chicken and turkey (white meat), it was more healthy than red meat.

Other than the red or white meats, seafood is derived from fish, and game is from nondomesticated animals. These may be sold fresh or frozen. Meat is also available in processed or manufactured products.

Meat is composed of three major parts: *muscle, connective tissue, and adipose tissue* (fat). Lean meats contain less adipose tissue than well-marbled cuts of meat. The location of the cut of meat on the animal, muscle contraction, and postmortem changes all influence the degree of meat tenderness. Individual cuts vary in inherent tenderness, requiring different cooking methods

All meat is subject to mandatory *inspection* by the USDA and voluntary *grading*. After inspection alteration may occur due to processing methods including curing, smoking, restructuring, and tenderizing. Kosher and Halal inspections mean much more than having a religious official blessing.

Incomplete plant proteins of animal feed are resynthesized in meat, and it is important to know that only animal protein is a *complete* protein. Thus, if meat consumption is minimized or omitted from the diet, for any number of reasons, an individual must obtain similar nutrients from a nonmeat source, such as combination of various plants (Chap. 7).

The USDA estimates 2011 US per capita beef consumption at 57.4 lb, down 13 % from 10 years ago and down about 25 % from 1980. The 2012 USDA prediction was that Americans would eat less beef than they ate in 2011 (only 54.1 lb of beef on average). Reuters News Service reports that this low amount "an opportunity for beef companies and retailers to promote . . . higher-end cuts in supermarkets but in smaller portions (National Cattleman's Beef Association (NCBA)".

V.A. Vaclavik and E.W. Christian, *Essentials of Food Science, 4th Edition*, Food Science Text Series,
DOI 10.1007/978-1-4614-9138-5_9, © Springer Science+Business Media New York 2014

Beef demand has been up and down—depending on such things as health news and the economy. Yet, some individuals may have environmental, religious, vegetarian/flexitarian beliefs, or other concerns related to the consumption of meat, thus they might choose to avoid meat products, or consume meat minimally. The USDA recommends to "go lean with protein." See your personal intake recommendation for daily consumption by utilizing choosemyplate.gov.

Meat must satisfy the requirements of appearance, texture, and flavor, as well as nutrition, safety, and convenience. Therefore, if eating meat, in order to keep it safe, it becomes important to know the effects of storing and cooking meat on its various components.

Characteristics of Meat

Physical Composition of Meat

The physical composition of meat is composed of three tissues: muscle tissue, connective tissue, and adipose or fatty tissue. Each is discussed in the text below.

Muscle Tissue. Muscle tissue is referred to as the *lean* tissue of meat. It includes *cardiac, skeletal, and smooth muscle*. *Cardiac* muscle is located in the heart. *Skeletal* muscle, the primary component of the carcass, provides support for the weight of the body, and its movement, or locomotion. When a muscle is used, it serves to strengthen the bone to which it is attached (true in humans too). *Smooth* muscle is the visceral muscle, located for example, in the digestive tract, reproduction system, and throughout the blood vessels of the circulatory system.

Within the muscle cell membrane (Fig. 9.1), there are ***myofibrils*** containing alternating thin and thick protein filaments, namely the *actin* and *myosin*, which contract and relax in the living animal. They are varied in length, perhaps 1 or 2 in. long, and are very small in diameter. Each fiber is cylindrical, with tapered ends, and is covered by a thin connective tissue sheath called ***endomysium***. Small bundles of 20–40 fibers make up one primary bundle that represents the "***grain***" of meat. This primary bundle is surrounded by ***perimysium*** connective tissue.

CULINARY ALERT! In carving meats it is often recommended to cut "across the grain," thus shortening the fibers for enhanced tenderness.

Collectively, several primary bundles form a larger, *secondary* bundle that also contains blood vessels and nerves. As is the case with the primary bundles that make it up, each secondary bundle is also surrounded by ***perimysium*** connective tissue. In turn, several of the secondary bundles are surrounded by ***epimysium*** connective tissue dividing one skeletal muscle from another. In *between* the muscle bundles, there are blood vessels (capillaries) and small pockets of fat cells.

Connective Tissue. (mostly collagen and elastin) The connective tissue is made up of protein and mucopolysaccharides. It is located throughout the muscle (Fig. 9.1) and determines the degree of meat tenderness. Lesser amounts of connective tissue equates to meat that is more tender. Various types of connective tissue—the endomysium, perimysium, and epimysium, bind the muscle fibers in bundles to form the muscle.

The connective tissue extends beyond the muscle fibers to form *tendons*, which attach the muscle to bones and holds and connects various parts of the body. It also forms *ligaments*, attaching one bone to another. Additionally, the tough skin, or hide of an animal, is connected to underlying animal tissue by connective tissue.

It follows that meat containing a *high* degree of muscle tissue naturally has a *greater* amount of connective tissue to hold myofibrils and bundles in the muscle. ***Collagen*** is the most abundant protein found in mammals—in bone, cartilage, tendons, and ligament, enveloping muscle groups and separating muscle layers. It is also in horns, hooves, and skin.

Collagen is a triple-coil protein structure that is white in color and contracts to a thick mass when heated. Yet, it becomes tenderized when cooked with *moist* heat. This tenderization may be referred to in several manners. For example,

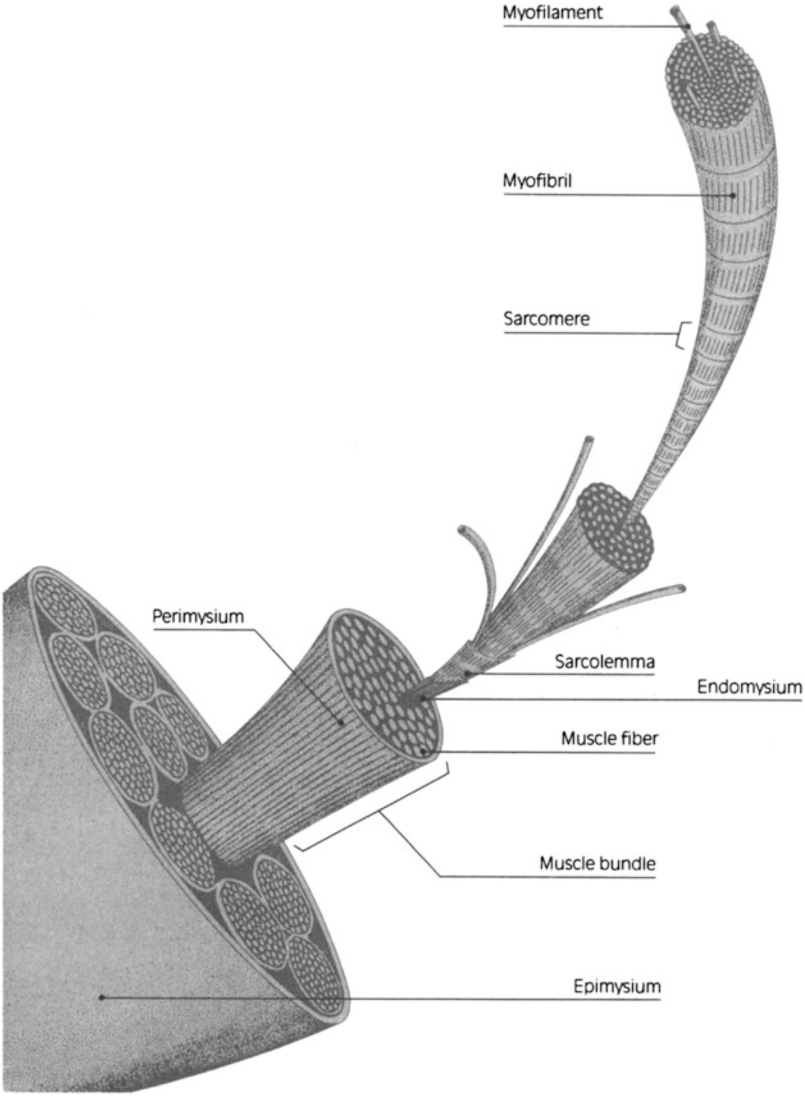

Fig. 9.1 Diagram of a lean muscle and its connective tissue (*Source*: National Cattlemen's Beef Association)

collagen may be "*converted to*," "*solubilized to*," or "*gelatinized to*" water-soluble ***gelatin***. (This is the same gelatin that may in turn be used for edible gels in the diet.) In older animals, the collagen is increased and may form many cross-linkage, thus *preventing* solubilization of collagen to the more tender gelatin. The meat from older animals is therefore tough.

A second, *lesser* component of the meat's connective tissue is the yellow-colored ***elastin*** protein, which is more elastic than collagen. It is found in the flexible walls of the circulatory system and throughout the animal body, assisting in holding bone and cartilage together. Elastin is extensive in muscles used in locomotion, such as legs, neck, and shoulders. Unlike collagen, it is *not* softened in cooking.

Another minor connective tissue component is ***reticulin***. This is a protein found in *younger* animals. It may be the precursor of collagen or elastin.

Usually, connective tissue is present to a greater degree in the muscle of *older* animals. Meat high in connective tissue may be mechanically *ground* to break the connective tissue and increase tenderization of the meat.

Fatty Tissue. A third meat component in addition to the muscle tissue and connective tissue is fatty tissue. Cuts of meat may vary substantially in composition and appearance due to the presence of ***adipose*** or ***fatty tissue***. Animal fat stores energy, and its content is dependent on factors such as animal feed, hormone balance, age, and genetics.

Fat is held by strands of connective tissue throughout the body and is deposited in several places such as around organs, under the skin, and between and within muscles as described below.

- **Adipose tissue**—fat that is stored around the heart, kidney organs, and in the pelvic canal areas. (*Suet* refers to the hard fatty tissue around the kidneys and other glandular organs of cattle and sheep.)
- **Subcutaneous fat** (finish)—fat that is visible after the skin is removed. (This is also referred to as *cover fat*. If well trimmed, the visible fat layer is less apparent.)
- **Intermuscular fat**—fat *between* muscles (also known as seam fat).
- **Intramuscular fat**—fat *within* muscles (marbling) (Fig. 9.2).

Upon cooking, the melted fat component contributes to juiciness, the sensation of tenderness, and flavor. Thus, well-***marbled*** meat with intramuscular fat may be desirable (despite the high level of fatty tissues). *Lean* meat is primarily muscle tissue and is *lower* in fat. The percentage of fat stores in an animal will generally increase with the animal's age.

Chemical Composition of Meat

The *chemical* composition of various meat cuts varies to a large degree from one cut to another. Meat may contain a range of 45–70 % water, 15–20 % protein, and anywhere from 5 to 40 % fat, depending on the cut and trim. Meat contains no carbohydrate (except for the liver, which stores glycogen). These meat constituents are described in the following text.

Water

Water is the major constituent of meat, and the *greatest percentage* is found in *lean* meat and young animals where *fatty tissue* is *low*. Then, as an animal becomes more mature and fatter, with more adipose tissue, the water forms a *smaller proportion* of the entire makeup compared to young, lean animals.

Water exists in muscle fibers and, to a lesser degree, in connective tissue. It is *released* from the protein structure in a number of ways. For example, water loss occurs as the muscle coagulates during cooking. Loss occurs as muscle fibers are broken (due to chemical, enzymatic, or mechanical tenderization), by salting, and if the pH changes. Inversely, water may be *added* to meats such as cured ham, with a notation appearing by law, on the ham label.

CULINARY ALERT! A recent repercussion of labeling that meets the government's food safety requirements of raw meats and poultry is that an identification of water retention must be stated. Thus, according to the USDA, processors must list either the maximum percentage of absorbed water, or retained water on applicable food labels.

Protein

Protein of *animal* sources is of *high* biological value. It is known as a *complete* protein, indicating that it contains all of the essential amino acids in amounts and proportions that can be used in synthesizing body proteins. The three primary types of proteins in meats are *myofibril*, *stromal proteins*, and *sarcoplasmic proteins* as described in the following:

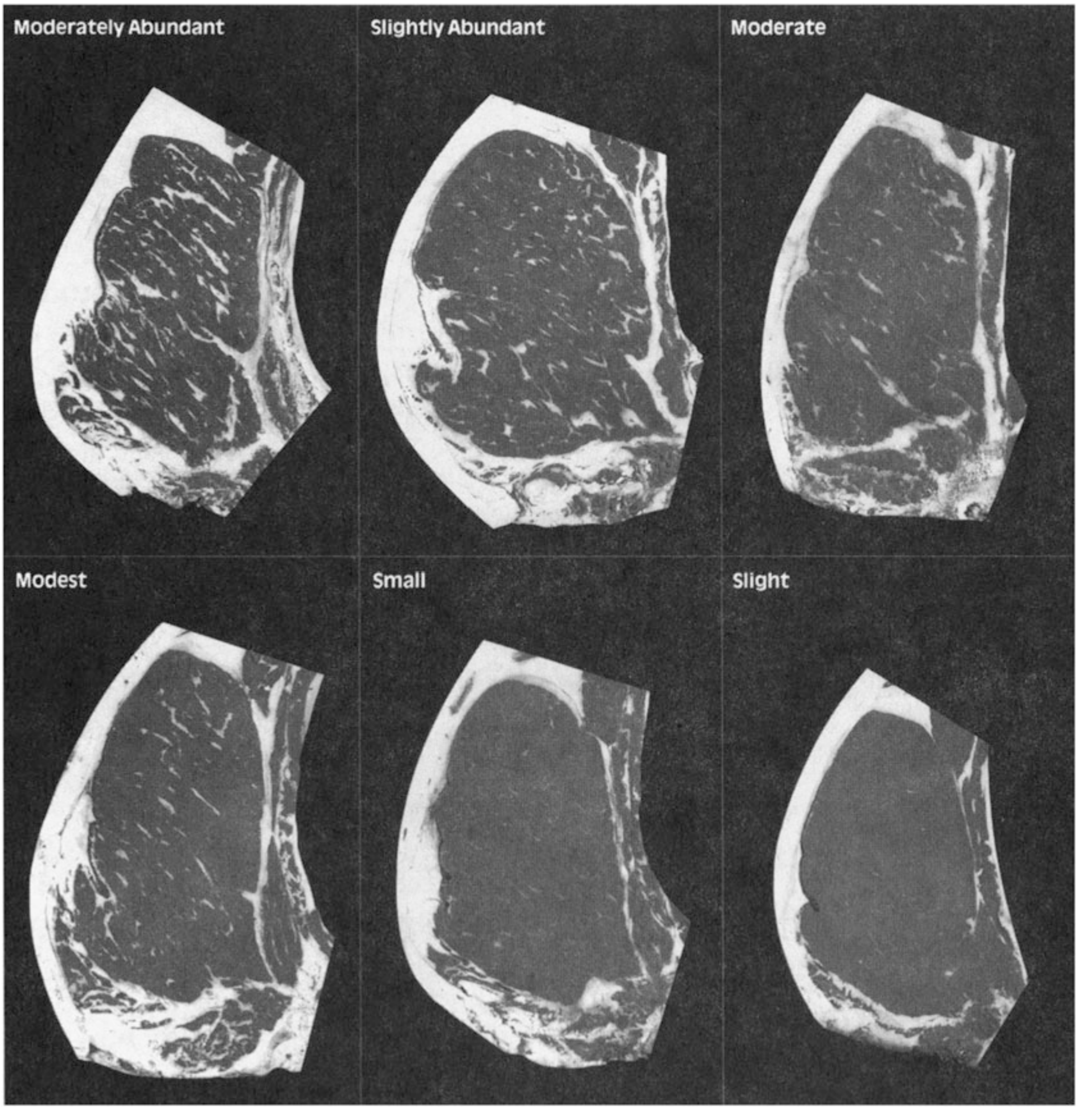

Fig. 9.2 Different levels of fat marbling (*Source*: National Cattlemen's Beef Association)

Myofibril proteins: Muscle bundles are groups of *myofibrils* composed of several protein molecules including actin and myosin that may form an overlap complex called ***actomyosin***.

Stromal proteins (connective tissue proteins): The watery connective tissue contains fibrils of *stromal* proteins: collagen, elastin, and reticulin (discussed earlier).

Sarcoplasmic proteins: *Sarcoplasmic* proteins are a third general classification of meat proteins. They include the *pigments* and *enzymes*. For example, the hemoglobin *pigment* stores oxygen in the red blood cells bringing it to tissues, including the muscles, while myoglobin stores oxygen in the muscle where it is needed for metabolism.

Enzymes are found in meat proteins. They may be *proteolytic*—degrading protein during the aging of meat, *amylolytic*—degrading carbohydrates, or *lypolytic*—degrading fats. There are also numerous enzymes in fluid of the muscle cell.

Fat

Fat may be a major component of meat. Fat varies in its degree of saturation (see Fig. 9.2). For example, subcutaneous fats are generally more *unsaturated* than fat around glandular organs. *Saturated* fat promotes less oxidation, and therefore less rancidity. In the animal, fat contributes to the survival of the living animal at low environmental temperatures.

In the diet, fat allows the fat-soluble vitamins A, D, E, and K to be carried. As well, fats contain some essential fatty acids that are the precursor material used in the synthesis of phospholipids for every cell membrane

Cholesterol, a sterol, is present in the cell membranes of all *animal* tissue. Typically, lean meats have a lower cholesterol content than higher fat meats. An exception to this level of existence of fat and cholesterol in lean meat is veal (young, lean calf meat), which is *low* in fat, yet *high* in cholesterol.

Carbohydrates

Carbohydrates are plentiful in *plant* tissue; however, are negligible in *animal* tissue. Approximately half of the small percentage of carbohydrates in animals is stored in the *liver* as *glycogen*. The other half exists throughout the body as glucose, especially in muscles, and in the blood. A small amount is found in other glands and organs of an animal. If an animal is exercised or not fed prior to slaughter, low stores of glycogen appear in the liver and muscles.

Vitamins and Minerals

Both vitamins and significant minerals are present in meats. The *water-soluble* B-complex vitamins function as cofactors in many energy-yielding metabolic reactions. The liver stores the four *fat-soluble* vitamins - vitamins A, D, E, and K. The minerals iron (in heme and myoglobin pigments), zinc, and phosphorus are present in meat.

Muscle Contraction in Live Animals

Muscle tissue of slaughtered animals undergoes several changes *after* slaughter. In order to better understand the reactions that occur in meat and their effects on tenderness and quality, it is necessary to have a basic understanding of the structure and function of muscle in a live animal.

Structure of the Myofilaments of Muscle

As previously mentioned, muscle fibers contain bundles of myofibrils. The myofibrils themselves are composed of bundles of protein filaments as shown in Fig. 9.3. These include *thin* filaments, made mostly of ***actin***, and *thick* filaments, which contain ***myosin***. They are arranged in a specific pattern within a repeating longitudinal unit called a ***sarcomere***.

The thin filaments occur at each end of the sarcomere, and they are held in place by ***Z-lines***. The Z-lines define the ends of each sarcomere. The thick filaments occur in the center of the sarcomere, and they overlap the thin filaments. The *extent of overlap* depends on whether the muscle is contracted or relaxed. In a *relaxed* muscle, the sarcomeres are extended, and there is *not* much overlap of thick and thin filaments. However, a *contracted* muscle has a *lot* of overlap because the sarcomeres shorten as part of the contraction process.

The thin and thick filaments are interspersed between each other in the regions where they overlap. A cross-section of the myofibrils shows that each thick filament is surrounded by six of the thin filaments, and every thin filament is surrounded by three of the thick filaments. This facilitates interaction between the thin and thick filaments when contraction occurs (see "Post-mortem Changes in the Muscle" section).

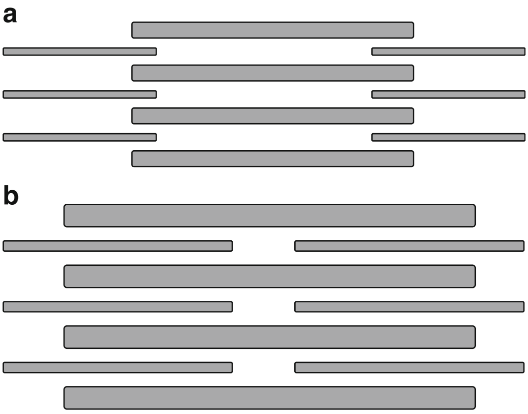

Fig. 9.3 Sarcomere and protein filaments (**a**) relaxed (**b**) contracted

Muscle Contraction

Muscle contraction starts when a nerve impulse causes release of calcium ions from the sarcoplasmic reticulum into the sarcoplasm, which is a jelly-like substance surrounding the thin and thick filaments of the myofibrils. The calcium ions bind to a specific site on the thin filaments, causing the active site on actin to be exposed. Actin molecules are then able to react with myosin, forming actomyosin. Adenosine triphosphate (ATP) is necessary as the energy source for this reaction.

The myosin then contracts and pulls the actin-containing filaments further in toward the center of the sarcomere. The actomyosin complex then breaks, and myosin forms another cross-link with a different actin molecule. As the cycle continues, the sarcomere continues to shorten, due to the formation of more cross-links, and contraction occurs.

When the nerve impulse ceases, calcium ions are pumped out of the sarcoplasm and returned to the sarcoplasmic reticulum. Actin and myosin cannot interact without calcium ions, and so the actomyosin complex breaks. The muscle relaxes and returns to its original extended state.

Energy for Contraction

The energy for contraction comes primarily from aerobic respiration, which enables glucose to be broken down completely to yield CO_2 and 36 molecules of ATP. In animals, glucose is stored as glycogen, which is broken down as needed to supply energy. When short bursts of extreme muscle activity are necessary, aerobic respiration does not supply adequate amounts of ATP, and so energy is also obtained by anaerobic glycolysis. This is a more rapid yet less efficient way of producing energy, as only two molecules of ATP are produced for every glucose molecule.

Glycolysis converts glucose to lactic acid, which builds up in the muscle. (It is the buildup of lactic acid that makes muscles sore and stiff after strenuous exertion. When the strenuous activity ceases, lactic acid is oxidized and removed from the muscle.)

Both aerobic respiration and glycolysis can take place in a *live* animal. *After* slaughter, aerobic respiration ceases, yet glycolysis continues for a while.

Postmortem Changes in the Muscle

Postmortem changes in the muscle make several meat characteristics differ. Some time *after* slaughter (from 6 to 24 h), muscle *stiffens* and becomes hard and inextensible. (Perhaps you have seen this stiffness in deer or other deceased animals in roadside accidents, or hunting sites.) *Prior* to slaughter, muscle tissue in the living animal is *soft and pliable*. Then there follows a time period for stiffening. It is species-specific, and it is known as ***rigor mortis***, which literally means “the stiffness of death.” This stiffening is due to loss of extensibility by the myofibril proteins, actin, and myosin, once *energy reserves* become nonexistent, and oxygen does not reach the cells.

If meat is cooked at this stage, it is extremely *tough*. In fact, most meat is *aged or conditioned* to allow the muscles to relax and become *soft and pliable* again before it is cooked. This “*resolution of rigor*” is due to the enzymatic breakdown of proteins that hold muscle fibers together. This stiffness is temporary.

Subsequent to slaughter, a sequence of events takes place in muscle that leads to the onset of rigor mortis. When the animal is killed, *aerobic* respiration ceases, blood flow stops, and the muscles are no longer supplied with oxygen. Therefore, *anaerobic* conditions soon prevail. Glycolysis continues, and glycogen stores are converted to lactic acid with the formation of ATP. The reaction continues until glycogen stores are depleted or until a pH of 5.5 is reached. At this pH, the enzymes that are responsible for glycolysis are denatured, and so the reaction *stops*. If glycogen is in short supply, glycolysis may stop due to depletion of glycogen, before the pH drops as low as 5.5.

When glycolysis stops, the ATP supply is quickly depleted. Lack of ATP prevents calcium ions from being pumped out of the sarcoplasm, and so the active site on the actin molecules of the thin myofilaments is available to bind with the myosin of the thick filaments. Actin and myosin unite, forming *actomyosin cross-links*. This cross-link formation is irreversible, as there is no available ATP. (In a live animal, actomyosin cross-links are formed and broken repeatedly, as part of contraction, though the cycle requires ATP.)

Formation of these irreversible *actomyosin cross-links* causes the muscle to become rigid. This is *rigor mortis*, and it correlates with the depletion of ATP in the muscle. Once formed, *actomyosin cross-links* do not break down, even during aging of meat, and their presence makes meat tough (Fig. 9.3b).

Accordingly, the stiffness of the muscle at rigor depends on the extent of actomyosin formation, which, in turn, depends on the extent of *overlap* of the thin and thick myofilaments. Recall that the *greater* is the overlap of thin and thick myofilaments, the more *extensive* the formation of actomyosin, and the *stiffer* the muscle. This results in *tough* meat:

- Little overlap—few actomyosin cross-links (tender meat)
- Substantial overlap—many actomyosin cross-links (tough meat)

Since the extent of actomyosin formation affects the toughness of meat, it is important to *minimize* the number of *cross-links* formed. This is done in two ways:

1. The meat is *hung* on the carcass after slaughter to *stretch* the muscles. This minimizes shortening of the sarcomeres and results in formation of *fewer* actomyosin cross-links. (more later).
2. *Pre-rigor temperature* is controlled to minimize fiber shortening. The optimum temperature is between 59 °F and 68 °F (15–20 °C). *Above* this temperature, increased shortening occurs. *Below* it, “cold shortening” occurs. At low temperatures, the sarcoplasmic reticulum pump is unable to pump calcium ions out of the sarcoplasm, and so contraction occurs.(more later).

Both hanging the carcass and controlling pre-rigor temperature minimize contraction before the onset of rigor mortis, result in fewer actomyosin cross-links, and increase meat tenderness.

Ultimate pH

The *ultimate pH* is the pH that is reached when glycolysis ceases and is usually around 5.5. After slaughter, the pH drops due to the buildup of lactic acid, which is normally removed from the blood of the living animal. As mentioned already, glycolytic enzymes are close to their isoelectric point and are inactivated at this pH, thus preventing glycolysis from continuing. Therefore, a pH of 5.5 is the lowest possible ultimate pH. It is possible to obtain a higher ultimate pH if the animal is starved or stressed before slaughter. This depletes the glycogen reserves, thus glycolysis stops before sufficient lactic acid has been formed to bring the pH to 5.5.

Meat with a high ultimate pH has excellent water-holding capacity, because many of the proteins are not as close to their isoelectric point and, therefore, are able to bind more water. However, a low ultimate pH is desirable from a microbiological point of view, because it inhibits microbial growth. A high ultimate pH results in poor resistance to microbial growth.

The *rate of change* of pH after slaughter also has a significant effect on the quality of meat. A *rapid* pH change while the temperature is still high causes considerable denaturation of contractile and/or sarcoplasmic proteins and loss of water-holding capacity. Lysozomal enzymes are also released at high temperatures, and these cause hydrolysis of proteins. Such *undesirable* changes may happen if the carcass is *not* cooled rapidly after slaughter (e.g., if the pH drops to 6.0 before the temperature of the carcass drops below 95 °F (35 °C)).

Aging or Conditioning of Meat

Natural ***aging*** or conditioning of meat involves holding meat for several days, beyond rigor mortis. Under controlled storage conditions of temperature and humidity, (and perhaps light) the muscles become soft and pliable again, making the meat tender. Meat aging occurs as muscles become tender due to (protein and) actomyosin breakdown. A protease, which is active at around pH 5.5, breaks down the thin myofilaments at the *Z*-lines. This causes the muscle to become pliable again, and meat to be tender. The sarcoplasmic proteins denature and there is some denaturation of the myofibril proteins, with a resultant loss of water-holding capacity, and so the meat drips. Collagen and elastin do not denature significantly during aging.

CULINARY ALERT! Natural, proteolytic enzymes in meat may sufficiently tenderize meat in the time between slaughter and retail sale; however, controlled aging is sometimes induced.

As mentioned above, actoyosin formation affects the toughness of meat, and it is important to minimize the number of cross-links formed. This is done in two ways. Aging is achieved by *hanging* the carcass in a cold room, at 34–38 °F (2 °C) for 1–4 weeks. Although the meat regains tenderness after about a week, the best flavor and tenderness develops in about 2–4 weeks. Humidity levels of approximately 70 % are controlled, and the meat may be wrapped in vacuum bags to minimize dehydration and weight loss.

Higher temperatures for shorter times, such as 68 °F (20 °C) for 48 h, have also been used to age beef. However, development of surface bacterial slime tends to be a problem for meat aged by such methods. It is shown that exposing the meat to ultraviolet light during the aging is of help in this regard.

Aging requirements differ among meat types. For example, pork and lamb do *not* require aging such as occurs with beef, since the animals are slaughtered while they are young and inherently tender. They are usually processed the day following slaughter.

Meat Pigments and Color Changes

Various meat pigments and color changes are seen in meat tissue. Meat may appear as red meat or white meat, depending upon the predominant pigment and its concentration contained in the meat. The two major pigments in meat responsible for the red color are myoglobin and hemoglobin. *Myoglobin* (with one heme group as part of its structure) is 80–90 % of the total meat pigment (see "Chemical Composition of Meat" section). It allows oxygen to be stored in the muscles. *Hemoglobin* (with four heme groups in its structure) is present at levels of 10–20 % of well-bled meat. It carries oxygen in the bloodstream.

Myoglobin, the primary pigment contributor of meat, is purplish-red. It is present in frequently exercised portions of the animal that expend great amounts of oxygen, such as muscles of a chicken leg. It produces the "dark meat" of turkey for example. The specific myoglobin level is influenced by the species, age, sex, and specific muscle. There is *more* myoglobin in the muscles of cows than pigs, *more* in older sheep than young lambs, and *more* in bulls (adult males) than cows.

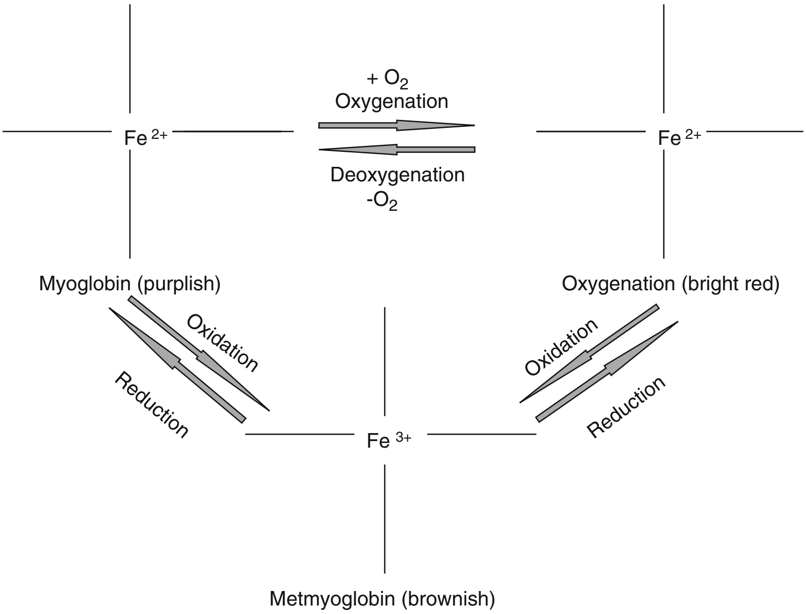

Fig. 9.4 Pigment change

When *myoglobin* is exposed to oxygen in the air, bright red, oxygenated *oxymyoglobin* is produced. With time, *metmyoglobin* is apparent. It is the *undesirable*, brownish-red colored pigment found in meat due to oxidation of the iron molecule. This unwelcome metmyoglobin pigment is found in meat that is *not* fresh, that contains significant levels of bacteria, and in meat exposed to light or exposed to low levels of oxygen (Fig. 9.4).

In processed meats, such as lunchmeats, nitrites may be added in order to both preserve the desirable pink color and control the growth of *C. botulinum*.

Meat-Handling Process

USDA Inspections

"*United States Inspected and Passed*" and the packaging/processing plant number is specified in the round *stamp* (Fig. 9.5) found on the primal cut of inspected meat. The stamp is made of a nontoxic purple vegetable dye. Packaged, *processed* meat must show a somewhat *similar stamp* on the packaging or *carton* of the meat. It is common for specific *state* inspection stamps (as opposed to USDA) to display a stamp with the shape of the state. Inspections for *wholesomeness* and accurate *labeling* are a service of the US government and are paid for with tax dollars.

The *Federal* Meat Inspection Act of 1906 requires inspection of all meat packing plants slaughtering and processing meat for *inter*state commerce. The Wholesome (Wholesale) Meat Act of 1967 required the same inspection program for *intra*state transport.

Trained veterinarians and agents of the USDA **Food Safety and Inspection Service** (FSIS) inspect the *health* of the animal, as well as *the sanitation* of the physical meat plant. The inspection for meat is *mandatory* (Chap. 20). Meat's inspection for ***wholesome****ness* indicates that it is safe to eat, without adulteration, and that examination of the carcass and viscera of the animal did *not* indicate the presence of *disease*. (It is *not* meant to imply freedom from all disease-causing microorganisms.)

Inspections occur *before*, *after*, and *throughout* meat processing. Diseased and unwholesome animals may *not* be used; harmful ingredients may *not* be added; misleading names or labels may *not* be used, and there must be established sanitation codes for the plant. Safety in meat processing is of

Fig. 9.5 The USDA inspection, quality grade, and yield grade stamps (*Source*: USDA)

utmost importance to the processor and customer alike. Violations of the Meat Act are fined and persons committing violations have been imprisoned! The Meat Inspection Program also controls and monitors *imported* meat.

In view of the fact that the pathogenic microorganism E. coli 0157:H7 may be undetected if *only visual inspections* are used for inspection, actual *bacterial counts* are included in inspections. Meat processing inspections with the inclusion of bacterial count checks now include the *Hazard Analysis and Critical Control Point* (HACCP) method of food safety (Chap. 16). It is the current program for inspecting meat.

> As far as USDA is concerned, its FSIS holds that a meat or poultry product can claim to be "natural" as long as it does not contain any artificial flavor or flavoring, color ingredient, chemical preservative or any other artificial or synthetic ingredient, and that the product and its ingredients are not more than minimally processed. Reports Hoffman at Solae regarding USDA's stance on "natural". (Decker 2013)

Kosher Inspection

Kosher inspection indicates that the meat is "*fit and proper*" for consumption or "*properly prepared*". Following Mosaic and Talmudic Laws, a specially trained rabbi slaughters the animal, e.g., beef, lamb, goat, and the meat is well-bled, and then salted. All processing is done under the supervision of individuals authorized by the Jewish faith. According to Mosaic Law, meat *must* come from an animal that has split hooves and chews its cud. Therefore, hogs and all pork products *cannot* be Kosher (see "Why Americans Buy Kosher" below).

The Kosher stamp (Fig. 9.6) does not indicate grade or wholesomeness. Meat is *still* subject to federal or state inspection.

Kosher Industry Facts

Why Americans Buy Kosher

55 %—Health and safety
38 %—Vegetarians
16 %—Eat halal
35 %—Taste or flavor
16 %—Guidelines that they were produced
8 %—Good products
8 %—Keep kosher all the time
8 %—Looking for vegetarian products, either for religious or dietary reasons

(Note: Respondents gave multiple answers)

Compiled by Lubicom Marketing and Consulting (2009)

Overall, there is an "estimated sales of kosher meat with 45 % being glatt or strictly kosher: $550,000,000" (Lubicom Marketing and Consulting, LLC, Brooklyn, NY http://www.lubicom.com/kosher/statistics/). Muslims and of other religious groups comprise a large percent of the Kosher market. Of course, not all persons of Jewish faith keep Kosher in their diet.

Kosher is not considered an acceptable substitute for proper and permitted Muslim foods. Only *some* foods are acceptable in also meeting Halal certification for Muslim requirements.

Fig. 9.6 Kosher Symbol (*Source*: National Cattlemen's Beef Association)

Halal Certification

The ***Halal*** certification indicates "*proper and permitted*." Only foods prepared and processed under Halal standards are to be consumed by Muslims, although not all persons of the Muslim faith keep to a diet of solely Halal-certified foods.

Certification uses trained Muslim inspectors who assist, participate in, and supervise food production in companies complying with Halal standards. A *crescent M* symbol on the product package indicates that the product meets the Halal standards of the Islamic Food and Nutrition Council of America (Food Technol 2000).

The types of foods permitted, including use of additives, slaughtering, packaging, labeling, shipping, and other aspects of food handling, are *regulated*. For example, the halal production does *not* accept alcohol, gelatin prepared from swine (for use as a food ingredient or packaging ingredient), or meat from animals that was *not* individually blessed.

Halal does not employ the same processing as Kosher food, although some products bear certification that they *are both* Kosher and Halal (Eliasi and Dwyer 2002). As per the founder and president of a company producing both Kosher and Halal refrigeration-free meals, a Kosher or Halal food product means much more than having the product blessed by a representative religious official.

In brief, there exist over 13 million persons of the Jewish faith, and one billion Muslims in the world. Their dietary laws are *not* interchangeable, yet are *similar*. A look at dietary restrictions of other religions is included in another reference (Food Technol 2000). As is true for Kosher, the Halal Certification does not indicate grade or wholesomeness. Meat is *still* subject to federal or state inspection.

Fig. 9.7 Halal certification (*Source*: Islamic Food and Nutrition Council of America)

The Halal stamp of certification (Fig. 9.7).

Grading of Meat

Voluntary grading of meat is part of the processing cost and is *not* paid for by tax dollars. The task of *grading* of meat (as opposed to the inspection of carcasses) was established by the USDA in 1927. It reports on both *quality* and *yield*, as described below (Fig. 9.5).

Voluntary *quality* grading evaluates various characteristics of animals. Evaluation includes age; color of lean, external fat quality and distribution, marbling; shape of animal carcass; and firmness of the muscle and meat texture—coarseness of muscle fiber bundles. So it looks at an evaluation of marbling, maturity, texture, and appearance.

Beef grades are according to the grades listed below. *Other* meats have *different* standards with less categories of grades.

- Prime
- Choice
- Select
- Standard
- Commercial
- Utility
- Cutter
- Canner

Prime grades of beef are very *well*-marbled. Prime is followed by Choice, Select, and Standard rankings with *less* marbling. The younger animal is more likely to be tender and receive a grade of

Prime, Choice, Select, or Standard. Older, more mature aged beef typically qualify for Commercial, Utility, Cutter, or Canner grades.

As well as voluntary *quality* grading, meat is also graded for *yield*, which is useful at the wholesale level. The highest percentage of lean, boneless yield (usable meat) on the carcass is given an assigned yield grade of “1.” If yield of a carcass is *less*, the yield grade may be assigned a value as low as “5.” Sales and marketing of meat products are based on both grades and yields.

Hormones and Antibiotics

Hormone and antibiotic use in animals are both monitored by the FDA. *Hormones* may be used in animal feeds to promote growth and/or to increase lean tissue growth and reduce fat content. All hormone-use in animal feeding must be *discontinued* for a specified time period prior to slaughter and must be *approved* by the FDA. A random sampling of carcasses provides tests for and monitors growth hormone residues (growth promotants).

Antibiotics in animal feed, when not utilized properly, may also pose a food safety concern. Antibiotics have been used for well over half of a century to treat disease and the FDA monitors their use in animal feeds to prevent their transfer to man. *Subtherapeutic* doses of antibiotics do more than treat *already-existing* diseases; such doses may be used to *prevent* disease and promote growth of animals. With this practice, the *therapeutic* administration of antibiotics to humans may be rendered ineffective if antibiotic-resistant strains of bacteria are passed from the livestock to man. The National Academy of Sciences (NAS) concluded that they were “unable to find data directly implicating the subtherapeutic use of feed antibiotics in human illness.”

In order to protect human health, the FDA (even recently) has urged that specific antibiotics used to treat animals be removed from the market, if they have been found to compromise other drugs used in treating animals or humans. “There are many countries [such as Denmark] that do not allow antibiotics as growth promoters in farm animals” (Peregrin 2002a). See Question below:

Question of the Week

Do Hormones and Antibiotics Cause Health Problems in Humans?

Myth:

The use of antibiotics and hormone growth implants in livestock production is causing hazardous residues in beef and contributing to the development of health problems in humans.

Fact:

1. No residues from feeding antibiotics are found in beef, and there is no valid scientific evidence that antibiotic use in cattle causes illness resulting from the development of antibiotic-resistant bacteria.
2. Scientific authorities agree that use of hormone implants results in the efficient production of beef that is safe. (Montana State University)

Antibiotics that are used *solely* for the purpose of *animal* growth have often been debated. Unfortunately, as has been reported in the press involving *human* growth hormone, a small percentage of illegal users may stay just one step ahead of regulatory inspectors.

Animal Welfare Approval

Meat may be certified by Animal Welfare Approved, one of the leading advocates for humane livestock treatment. The first Animal Welfare Approved restaurant opened in Hudson, NY in 2011.

Cuts of Meat

Primal or Wholesale Cuts

A ***primal cut*** is also known as a *wholesale* cut of an animal. Meat cutting separates cuts into *tender* and *less tender* cuts, and *lean* and *fatty*. Cuts differ with species, and primal cuts of *beef* are identified below. They are listed according to tenderness. *Less exercised* skeletal muscles that provide support (as in: cuts of meat along the backbone, such as the loin) are usually more tender than other skeletal muscles that are used in *locomotion*. Ultimately though, tenderness is a function of how meat is torn by the teeth, not just the cut, age, and so forth.

Most tender	Medium tender	Least tender
Rib	Chuck	Flank (<brisket)
Short loin	Round	Short plate
Sirloin		Brisket
		Foreshank
		Tip

Subprimal Cuts

Subprimal cuts are divisions of *primal* cuts, often sent to the grocery market for further cutting. They may be boneless. If they are vacuumpacked, they are considered as "beef-in-a-bag", if boxed, "boxed meat". Subprimal cuts are further divided into individual *retail* cuts such as roasts, steaks, and chops.

Retail Cuts

Retail cuts are those available in the *retail* market, cut from primal or subprimal cuts. They may be named for the primal cut in which they are located *or* for the bones they contain. (Fig. 9.8).

In most cases, the cuts from the neck, legs, and lower belly are *least tender* for the reason that, as mentioned, they are the most exercised portions of the animal. These cuts are made more palatable when cooked with *moist heat* to soften connective tissue, although the same less tender cuts may be cooked with *long*, dry heat cooking at low temperatures and produce a satisfactory product. *Tender* cuts are cooked with *dry heat*.

CULINARY ALERT!

- Less tender cuts—best: moist heat or long, low heat cooking
- Tender cuts—best: dry heat cooking, quick

The wholesale and retail cuts of beef are identified in Fig. 9.8. In the1970s, The National Livestock and Meat Board (now National Cattlemen's Beef Association (NCBA)) coordinated a committee of retail and meat industry representatives and federal agencies, which standardized names for 314 retail cuts of meat. They published the *Uniform Retail Meat Identity Standards* (URMIS). URMIS labels include the kind of meat (beef, veal, pork, or lamb), the primal cut from which the meat originated (chuck, rib, loin, or round of the animal), and the name of the retail cut.

Beef (Fig. 9.11) is *most commonly* obtained from carcasses of the following:
- Steer: young, castrated male carcass
- Heifers: young, females before breeding, beyond veal and calf age

Beef is *less frequently* obtained from the carcasses of the following:
- Cows: females that have had a calf
- Bulls: adult male
- Baby beef: young cattle, 8–12 months of age
- Calves: young cattle, 3–8 months of age, beyond veal classification

Veal is from the carcass of:
- Beef calves, generally 3 weeks to 3 months or more.
- Veal is milk-fed, not grass-fed, thus is low in iron and pale in color.
- Young calf meat is normally lighter pin-gray than older calf meat.

Pork is the flesh of swine (pig).
Lamb is the flesh of *young* sheep, not more than 14 months old.
Mutton is the flesh of sheep *older* than 2 years.

Cooking Meat

To better assure a successful cooked meat product, it is critical to know the effects of cooking meat on

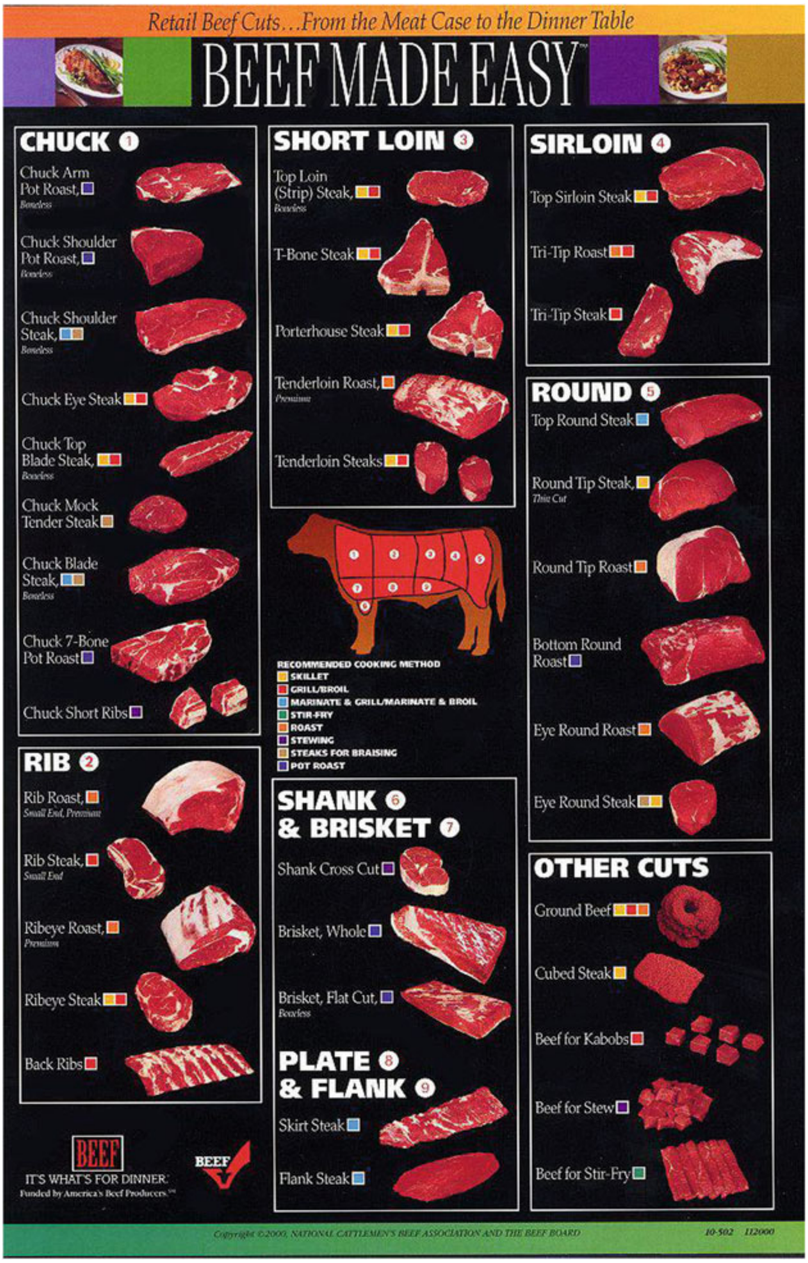

Fig. 9.8 Wholesale and retail cuts of beef (*Source*: USDA)

its various components. The processing plant and consumer both require a familiarity with types of cuts and cooking methods for meat. Although it may be a lot to ask, meat must satisfy the requirements of appearance, texture, and flavor, as well as nutrition, safety, and convenience.

Certainly, some individuals may have environmental, religious, vegetarian, health, or other concerns related to the consumption of meat, thus they might choose to *avoid* meat products, or consume meat minimally.

CULINARY ALERT! The purpose of cooking is to improve appearance, tenderness, and flavor while destroying pathogenic microorganisms.

In cooking, the peptide chains of amino acid chains uncoil (denature) and reunite or coagulate, releasing water and melted fat (Chap. 8). Consequently, the meat shrinks. When heat is applied, muscle fibers toughen and connective tissue becomes tender. These reactions are opposing effects and the method, time, and temperature of cooking differ.

Effects of Cooking on Muscle Proteins

Cooking has an effect, both desirable, and more negative on muscle proteins. The muscles used in locomotion (muscles for physical movement), as well as muscles of older animals each contain a large number of myofibrils in each muscle. As opposed to this, the less-used muscles and muscles of young animals have less myofibrils in each muscle. Thus, in the former case, muscle bundles are physically larger, and the large size indicates that they have a more coarse grain.

Temperatures around 131 °F (55 °C) precipitate myosin, and 158–176 °F (70–80 °C) precipitates actin. This precipitation denatures, shortens, toughens, and shrinks the surrounding connective tissue, causing a loss of water-holding capacity. The longer the cooking time, the more serious this effect will be, although at temperature of 170 °F (77 °C) tenderness may improve.

Tender cuts of meat contain *small* amounts of connective tissue and should be cooked for a short time at a *high* temperature with dry heat. Such cooking minimizes coagulation and shrinkage of muscle fibers and prevents loss of water-holding capacity. Toughening of the muscle fibers is minimized if tender cuts are cooked to *rare* rather than the well-done stage.

Tender meat that is *overcooked* tends to be *dry and tough* because the protein coagulates, water is squeezed out, and myofibrils toughen. Greater cooking intensity for a short time is advantageous for tender cuts of meat, and prolonged moist heat cooking is recommended for *less tender* cuts of meat.

Effects of Cooking on Collagen

As the collagen in meat is subject to the heat of cooking, the effect is that hydrogen bonds and some heat-sensitive cross-links are broken. Collagen, as mentioned earlier, is the major component of connective tissue. At temperatures between 122 °F and 160 °F (50–71 °C), connective tissue begins shrinking. Some of the tough-structured collagen is then solubilized and converted to gelatin. As the collagen fibers are weakened, the meat becomes more tender. Breakdown (or “melting,” solubilization, gelatinization) of collagen is faster as collagen reaches higher temperatures.

Young animals contain few cross-links in collagen thus, it is readily converted to gelatin and meat tends to be tender. Collagen from *older* animals, on the other hand, contains many more covalent cross-links, most of which are *not* broken down by cooking; therefore, older animals yield tough meat unless it is heated in a *moist* atmosphere.

Cuts of meat *low* in collagen, such as rib or loin steaks, are inherently tender and do *not* benefit from slow, moist heat cooking. These cuts are more tender when cooked *quickly* and served to the *rare* or *medium-rare* stage.

On the other end of the spectrum, when collagen levels in a cut of meat are *high*, slow, moist heat cooking, to achieve a *well-done* stage, is recommended as it gelatinizes the collagen. Some tenderization of the meat surface (1/4 in.) occurs as meats are placed in marinades.

Effect of Cooking on Fat

The effect of cooking on fat is seen as fat melts throughout the meat with cooking. This melted fat produces a perception of a tender product. If a cut is high in fat content, or well-marbled, it yields a more tender cooked meat. In cooked, left-over meat, fat oxidation contributes to flavor deterioration.

Methods of Cooking

Normally, as mentioned previously, there are various “best” methods of cooking—dry heat and moist heat.

- ***Dry heat*** **methods** of cooking include broiling, frying, pan-frying, roasting, sautéing, and stir-frying. Meat is cooked *uncovered*. *Tender* steaks, chops, ground meat, and thin cuts are cooked this way
- ***Moist heat*** **methods** of cooking include braising, pressure-cooking, simmering, steaming stewing, or using a slow cooking pot to simmer. Meat is cooked *covered*. *Less tender* cuts such as chuck, flank, or round may be cooked in this manner

Meat contains water and therefore, to some extent, *all* meat if it is covered, provides moist heat cooking. This reduces surface drying that occurs with dry heat cooking and gives time for collagen to become gelatin.

The effect of *dry* heat (uncovered) and *moist* heat (covered) on two *identical*, less tender cuts of meat such as the chuck or round is seen. When the two roasts are removed from the oven at the *same* time, the *covered* roast temperature shows a lower temperature and less weight loss than the *uncovered* roast. Covering is preferable for these less tender cuts.

Other Factors Significant in Cooking

Cooking *methods* have previously been discussed. However, additional factors are significant in cooking. For example inherent pigments, the reading of thermometers, searing, and removal temperature are important factors in cooking. They are discussed in the following:

Pigments. Color may be an indication of the degree of doneness. When cooked, the myoglobin pigment is denatured, and therefore meat changes color from a red or purple, to pale gray-brown.

Use of Thermometers. The use of a calibrated thermometer to measure temperature provides the necessary assurance that the recommended safe cooking temperature is achieved. The cooking thermometer may be designed to detect *multiple* food temperatures along its stem and show an "average" temperature of those multiple readings. Depending upon where/how the thermometer is inserted—into the fat, muscle, or placement near a bone, the reported temperature varies and may not accurately reflect doneness.

CULINARY ALERT! The thermometer will give a false reading if placed in the fat or touching a bone. Thermometers provide a more accurate reading of meat doneness when they are inserted at an angle, rather than vertically where fat could drip down the stem, and again, give a false reading.

Searing. Initial high heat, or the short practice of "searing" with *dry* heat imparts flavor; however, further *moist* heat cooking is used for the continued cooking of less tender cuts of meat, high in collagen-containing connective tissue.

Removal temperature. Large roasts increase in internal temperature for 15–45 min or more *after* removal from the oven. Roasts removed from the oven at the *rare* stage (more moisture) exhibit a *greater* temperature rise following removal from the oven, than roasts removed at the drier, *well-done* stage. This should be kept in mind when a specific doneness is desired.

Specific temperatures for doneness of meat are as follows:

Doneness	Temperature
Rare	140 °F (60 °C)
Medium-rare	150 °F (65 °C)
Medium	160 °F (71 °C)
Well done	170 °F (77 °C)

CULINARY ALERT! Roasts increase in temperature following removal from the oven. Use a calibrated thermometer correctly.

Alterations to Meat

Processed Meat

Processed meat is defined as meat that has been changed by any mechanical, chemical, or enzymatic treatment, altering the taste, appearance, and often keeping the quality of the product (NCBA). It may be cured, smoked, or cooked, and it includes cold cuts (lunch meats), sausage, ham, and bacon. Processed meats may be available in low-fat formulations. Meat that has been processed is subject to the same USDA inspection as other meat.

Of all the meat produced in the United States, about one third is processed meat. Most of processed meat is *pork*, approximately one quarter of it is *beef,* and a small amount is *lamb or mutton*. If formulated with meat trimmings and variety meats, that fact must be stated on the label.

Processed meats may contain salt, phosphates, nitrate (NO_3), or nitrite, which provide beneficial *microbial control*. Additionally, these ingredients supply flavor, texture, and protein-binding contributions (see Restructured Meats) to foods. Processed meats may contain a reduction or replacement of sodium. Sectors of the population watching sodium or some additives may desire to reduce their intake of processed meat. Lower sodium processed meat is also discussed under the Nutrition section of this chapter.

The FSIS allows specific additions to meat. *Carrageenan*, and locust bean gum, may be utilized as meat additives. *Xanthan* gum at maximum levels of 0.5 % to prevent escape of the brine solution added to cured pork products is allowed. *Nitrite* is added to processed meat to preserve the color of meat and control the growth of *C. botulinum*.

A health concern regarding the addition of *nitrites* is that they could combine with amines (the by-product of protein breakdown) in the stomach and form carcinogenic “nitrosamines.” This was addressed in a report by the NAS that stated that neither sodium nitrate nor nitrite was carcinogenic. Nitrites remain at levels less than 50 ppm in processed meat at the point of consumption. Many processors add ascorbic acid (vitamin C), erythorbic acid and their salts, sodium ascorbate, and sodium erythorbate, to cured meat to maintain processed meat color. These same additives also inhibit the production of nitrosamines from nitrites.

What Nitrite Does in Meat

Nitrite in meat greatly delays development of the botulinum toxin (which causes botulism), develops cured meat flavor and color, retards development of rancidity and off-odors and off-flavors during storage, inhibits development of warmed-over flavor, and preserves flavors of spices, smoke, etc.

Adding nitrite to meat is only part of the curing process. Ordinary table salt (sodium chloride) is added because of its effect on flavor. Sugar is added to reduce the harshness of salt. Spices and other flavorings are often added to achieve a characteristic “brand” flavor. Most, but not all, cured meat products are smoked after the curing process to impart a smoked meat flavor.

Sodium nitrite, rather than sodium nitrate, is most commonly used for curing (although in some products, such as country ham, sodium nitrate is used because of the long aging period). In a series of normal reactions, nitrite is converted to nitric oxide. Nitric oxide combines with myoglobin, the pigment responsible for the natural red color of uncured meat. They form nitric oxide myoglobin, which is a deep red color (as in uncooked dry sausage) that changes to the characteristic bright pink normally associated with cured and smoked meat (such as wieners and ham) when heated during the smoking process. (http://www.extension.umn.edu/distribution/nutrition/DJ0974.html, University of Minnesota Extension)

Curing and Smoking of Meat

Curing is a modification of meat that increases shelf life, forms a pink color, and produces a salty flavor. As mentioned, cured meats contain nitrite that controls the growth of *C. botulinum*. Additional color changes to the cured meat may result in fading as the pigment *oxidizes* when exposed to oxygen. Exposure to *fluorescent light* may actually give cured hams a fluorescent sheen and also causes a graying or fading of the color. Therefore, cured meats are packaged so that they are *minimally* exposed to the deleterious effects of oxygen and light.

Very popular ***cured meats*** include ham (pork) and corned (cured) beef as well as bacon and pastrami. Corned beef was given the name for the reason that beef was preserved with “corns” (grains) of salt.

Smoked meats prepared on a smoker are very popular in parts of the United States; they are relatively unheard of in other localities. Commercially or at home, beef, ham, and turkey are smoked (heat processed) to impart flavor. Liquid smoke could also be used to impart flavor.

CULINARY ALERT! Smoking treats meat by exposure to the aromatic smoke of hardwood and smoking also dehydrates, thus offering microbial control to the meat.

FDA Ruling on Curing and Smoking

(A) Introduction

Meat and poultry are cured by the addition of salt alone or in combination with one or more ingredients such as sodium nitrite, sugar, curing accelerators, and spices. These are used for partial preservation, flavoring, color enhancement, tenderizing, and improving yield of meat. The process may include dry curing, immersion curing, direct addition, or injection of the curing ingredients. Curing mixtures are typically composed of salt (sodium chloride), sodium nitrite, and seasonings. The preparation of curing mixtures must be carefully controlled . . . It is important to use curing methods which achieve uniform distribution of the curing mixture in the meat or poultry product.

FDA—Smoking

Smoking is the process of exposing meat products to wood smoke. Depending on the method, some products may be cooked and smoked simultaneously, smoked and dried without cooking, or cooked without smoking. Smoke may be produced by burning wood chips or using an approved liquid smoke preparation. Liquid smoke preparations may also be substituted for smoke by addition directly onto the product during formulation in lieu of using a smokehouse or another type of smoking vessel. As with curing operations, a standard operating procedure must be established to prevent contamination during the smoking process.

Ham is cured pork from the hind leg of the hog. Picnic shoulder or picnic ham is made from the front leg of the hog. Bacon is cured and/or smoked hog meat from the pig belly. The University of Georgia, Cooperative Extension Service

Restructured Meat

Restructured meat contains muscle tissue, connective tissue, and adipose tissue of a natural cut of meat; however, proportions of each may differ. In the process of restructuring, meat is (1) flaked, ground, or chunked to a small particle size, (2) reformed, and (3) shaped—perhaps into roasts or steaks.

Myosin in the meat muscle may be instrumental in causing meat particles to bind together. As well, salts, phosphates, and other *nonmeat* binders such as egg albumen, gelatin, milk protein, wheat, or textured vegetable protein may be added for the purpose of holding protein particles together. Generally, the restructuring process provides a less expensive menu item that *resembles* a whole meat portion. It offers consistency in serving size and appearance. Most boneless hams and some breakfast meats are restructured meats.

Tenderizing, Artificial Tenderizing

Tenderizing meats may be desirable prior to cooking. *Young* animals are *naturally* tender and do not need *artificial* tenderizing. Recall that the connective tissue of *older* animals contains more covalent cross-links, is less soluble, and less readily converted to gelatin. Therefore, meat from older animals may require tenderization. In addition to the age, the origin of the specific cut on the animal is also a factor influencing tenderness.

The less tender cuts of meat may be *artificially* tenderized to break down the proteins of muscle or connective tissue. This may be achieved by mechanical, electrical, or enzymatic treatment as discussed below.

The *mechanical* tenderization includes chopping, cubing, and grinding. Meat may cubed, ground, or pounded prior to stuffing or rolling or use in a recipe. These techniques break the surface muscle fibers and connective tissue. A special instrument that pierces the meat with multiple thin, tenderizing needles is involved in the "needling" or "blade tenderizing" of meat.

Electrical stimulation such as ultrasonic vibration indirectly tenderizes meat by the physical vibrations that stimulate muscles to break down ATP to lactic acid. It also decreases the pH. The electrical stimulation of a carcass tenderizes without degrading the muscle fibers and texture of meats to a mushy state.

Natural *enzyme* tenderizers derived from tropical plants are available as powders or seasoning compounds that may be applied by dipping or spraying meat. They are more effective in tenderizing than marinades, which only penetrate approximately one fourth inch into the interior of the meat. Enzymes include papain from the papaya plant, bromelain from pineapple, and ficin from figs.

Various enzymes treat the muscle tissue, and others, the connective tissue. For example,

- The enzymes chymopapain, or papain, and ficin exert a greater effect on tenderizing *muscle fibers* than tenderizing connective tissue.
- The enzyme bromelain degrades *connective tissue* more than the myofibrils.

Any overapplication of natural enzyme tenderizers to meat surfaces, or allowing the treated meat to remain at temperatures conducive to enzymatic activity, could produce an *overly* soft meat consistency.

The natural enzyme tenderizer papain may also be injected into the jugular vein (bloodstream) of an animal a few minutes before slaughter. It is distributed throughout the animal tissue. The enzyme is heat-activated (by cooking at 140–160 °F (60–71 °C)) and eventually denatured in cooking.

CULINARY ALERT! With the addition of acid marinades to meat, collagen is softened to gelatin. The collagen fibers exhibit swelling and retain more water. Tomato and vinegar are acids that cause meat to respond in this manner and become tender.

There is a more *recent* development utilized in tenderizing meat without affecting appearance and taste. This is a *noninvasive process* used to tenderize meat: The process employs a 3 min cycle in a high pressure, water-filled, closed tank. A 4-ft diameter stainless steel tank, sealed with a stainless steel domed lid, creates a high-pressure wave as a small explosive charge is detonated within *the* tank. Lower grades of meat, especially cuts that are low in fat content, may increase in value as they are made more tender for consumer use (Morris 2000).

Poultry

Poultry (bird) sales increased in times when beef sales declined. All poultry is subject to *inspection* under the Wholesome Poultry Products Act of 1968 and is *graded* US Grade A, B, or C quality based on factors including conformation, fat, and freedom from blemishes and broken bones. The inspection, labeling, and handling of poultry products is similar to the meat inspection process (Chap. 19).

Chicken is the *primary* poultry consumed in the US diet. It is classified according to weight, age, and condition of the bird as follows:

Broilers/fryers	2–2.5 lb	3–5 months of age
Roasters	3–5 lb	9–12 weeks of age
Capons	4–8 lb	Less than 8 months of age
Hens, stewing hens, or fowls	2.5–5 lb	Less than 1 year
Rock Cornish game hen	1–2 lb	5–7 weeks of age

Turkey is the *second* most frequently consumed poultry in the United States and is classified as follows:

Fryers/roasterst	10 weeks of age
Mature roasting birds	20–26 weeks of age
Tom turkey (male)	greater than 5 months of age

Duck, geese, guinea, and pigeon provide variety to the diet; however, are consumed less frequently than chicken or turkey. Each is subject to inspection by the USDA's Food Safety and Inspection Service (FSIS).

The *dark meat* of poultry represents portions of meat from more exercised parts of the animal. Dark meat contains *more* myoglobin, and fat, and more iron and zinc than *white meat*. It also contains *less* protein. However, regarding fat content, any poultry *without* skin on during cooking allows less drippage of fat into meat than poultry cooked with the skin. It is possible that poultry *with* skin may contain slightly more of the lipid cholesterol than an equal portion of lean beef.

In addition to the *whole bird*, individual pieces of breast meat, legs, or thighs are sold separately, and there are many *processed* poultry products on the American market. For example, many *lunch meats* contain turkey or chicken which provides the benefit of poultry in place of beef or pork and may reduce fat content. *Ground turkey* may serve as a replacement for *ground beef* in cooked dishes, and many *formed entrees* such as nuggets, patties, or rolls are available to the consumer.

Proper poultry cooking is imperative as it may carry *Salmonella* bacteria. It must be adequately cooked (165° F) to assure destruction of this living pathogen. The FSIS allows the use of trisodium phosphate as an antimicrobial agent on raw, chilled poultry carcasses that have passed inspection for wholesomeness.

Fish

Fish is consumed by many people. It includes both edible *finfish* and *shellfish* (both appear in charts below) obtained from marine and freshwater sources. Fish is *softer* and *flakier* than either mammals or poultry, because muscle fibers exist as short bundles, which contain thin layers of connective tissue (see Fig. 9.9).

Worldwide, there are several thousand species of seafood, and with current processing, preservation, and marketing methods, a greater variety of species are consumed. Yet, only a few species are used as edible fish and shellfish (Fig. 9.9).

Fish are classified as follows:

Finfish (vertebrate with fins): Finfish are fleshy fish with a bony skeleton and are covered with scales. They may be lean or fat. For example:

Fig. 9.9 Fish (Courtesy of SYSCO® Incorporated)

Lean

- *Lean* saltwater fish—cod, flounder, haddock, halibut, red snapper, whiting
- *Lean* freshwater fish—brook trout and yellow pike

Fat

- *Fat* saltwater fish—herring, mackerel, and salmon
- *Fat* freshwater fish—catfish, lake trout, and whitefish

Shellfish (invertebrates): Shellfish are either *crustaceans or mollusks*—the former with a crustlike shell and segmented bodies, the latter with soft structures in a partial or whole, hard shell. Some examples are as follows:

Crustacea

- Crab, crayfish, lobster, and shrimp
- Crustlike shell and segmented bodies

Mollusks

- Abalone, clams, mussels, oysters, and scallops
- Soft structures in a partial or whole, hard shell

The physical, nutritive components of fish are similar to mammals—for example,

- Carbohydrate: negligible content, as is the case with mammals
- Fat: variable percentage, primarily liquid (hence, fish *oil*) and *not* saturated.
  - Fish feed on marine and freshwater *plants* that contribute to their high content of omega-3 polyunsaturated fatty acids. (Eicosapentaenoic acid—EPA, and docosahexaenoic acid—DHA, both demonstrated to be ‘protective against diseases, such as heart disease.)
- Protein: high quality, complete proteins including:
  - Myofibril proteins—actin and myosin;
  - Connective tissue—collagen; and sarcoplasmic proteins—enzymes and myoglobin.

In the past, the “R-Month Rule” stated that the months of September through April indicated safe harvesting of shellfish. The letter “R” is in their spelling and these are also colder months. Today, adequate refrigeration and care dispels this belief.

Fish is classified as inherently tender because fish contains *less* connective tissue than beef, and *more* of it converts to gelatin during cooking. The *flakes* that appear in a cooked fish are due to a change in connective tissue that occurs with heating and are a sign that cooking is complete.

CULINARY ALERT! The appearance of flakes in cooked fish indicates doneness.

Restructured, or “formed” fish of various types that have been minced prior to cooking will *not* show such flakes. *Minced fish* may be

10 tips
Nutrition Education Series

eat seafood twice a week

10 tips to help you eat more seafood

Twice a week, make seafood—fish and shellfish—the main protein food on your plate.* Seafood contains a range of nutrients, including healthy omega-3 fats. According to the *2010 Dietary Guidelines for Americans*, eating about 8 ounces per week (less for young children) of a variety of seafood can help prevent heart disease.

1 eat a variety of seafood

Include some that are higher in omega-3s and lower in mercury, such as salmon, trout, oysters, Atlantic and Pacific mackerel, herring, and sardines.

2 keep it lean and flavorful

Try grilling, broiling, roasting, or baking—they don't add extra fat. Avoid breading or frying seafood and creamy sauces, which add calories and fat. Using spices or herbs, such as dill, chili powder, paprika, or cumin, and lemon or lime juice, can add flavor without adding salt.

3 shellfish counts too!

Oysters, mussels, clams, and calamari (squid) all supply healthy omega-3s. Try mussels marinara, oyster stew, steamed clams, or pasta with calamari.

4 keep seafood on hand

Canned seafood, such as canned salmon, tuna, or sardines, is quick and easy to use. Canned white tuna is higher in omega-3s, but canned "light" tuna is lower in mercury.

5 cook it safely

Check oysters, mussels, and clams before cooking. If shells don't clamp shut when you tap them, throw them away. After cooking, also toss any that didn't open. This means that they may not be safe to eat. Cook shrimp, lobster, and scallops until they are opaque (milky white). Cook fish to 145°F, until it flakes with a fork.

6 get creative with seafood

Think beyond the fish fillet. Try salmon patties, a shrimp stir-fry, grilled fish tacos, or clams with whole-wheat pasta. Add variety by trying a new fish such as grilled Atlantic or Pacific mackerel, herring on a salad, or oven-baked pollock.

7 put it on a salad or in a sandwich

Top a salad with grilled scallops, shrimp, or crab in place of steak or chicken. Use canned tuna or salmon for sandwiches in place of deli meats, which are often higher in sodium.

8 shop smart

Eating more seafood does not have to be expensive. Whiting, tilapia, sardines, canned tuna, and some frozen seafood are usually lower cost options. Check the local newspaper, online, and at the store for sales, coupons, and specials to help save money on seafood.

9 grow up healthy with seafood

Omega-3 fats from seafood can help improve nervous system development in infants and children. Serve seafood to children twice a week in portions appropriate for their age and appetite. A variety of seafood lower in mercury should also be part of a healthy diet for women who are pregnant or breastfeeding.

10 know your seafood portions

To get 8 ounces of seafood a week, use these as guides: A drained can of tuna is about 3 to 4 ounces, a salmon steak ranges from 4 to 6 ounces, and 1 small trout is about 3 ounces.

*This recommendation does not apply to vegetarians.

USDA United States Department of Agriculture
Center for Nutrition Policy and Promotion

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DG TipSheet No. 15
December 2011

produced from less popular varieties of fish, or from the fish-flesh remains of the filet process.

The washed, minced fish, coupled with heating, produces gel-like properties in the flesh and it may be "*formed*" for use as various products. For example, with centuries of production in Japan, and developing technology in handling, the minced fish is used in the production of fish sticks, nuggets, patties, or other unbreaded, "formed" fish items.

In the production of *surimi*, for example, minced fish such as pollack is washed to remove both oil and water-soluble substances such as colors and flavor compounds, leaving only protein fibers as the remains. The washing also removes sarcoplasmic proteins that interfere with the necessary gelling. (Thus some oil and sarcoplasmic enzyme residue remaining in the fibers.)

Subsequent to washing, the flesh (protein fibers) is mixed with salt to solubilize the myofibril proteins—actin and myosin. Other characteristic flavors and pigments, as well as ingredients that promote the elastic texture and stability of the product, are added to the fish so that it may be incorporated into chowders, resembles crabmeat, lobster meat, or sausage-type products.

If surimi is used to create these crabmeat, lobster meat, or sausage-type products, they are called "imitation" (e.g., "imitation crabmeat."). Two of the more common raw fish dishes are sashimi and sushi. Sashimi is sliced and prepared fish and sushi if vinegared rice, rolled with raw fish, and covered with seaweed. Care in handling is required of raw fish dishes.

In addition to the aforementioned meat, poultry, and fish, other protein sources in the diet are listed below.

Dry Beans and Peas (Legumes) as Meat Alternatives

Legumes offer great variety of diet. As plant material, legumes are *incomplete* proteins, while *complete* proteins are animal proteins that contain all the essential amino acids present at superior levels—for example, meat, poultry, fish, or milk and eggs.

In order to obtain the same essential amino acid profile as complete proteins, two or more *plant* protein foods are typically *combined* and eaten in the same day. The requirement is that they are combined in a *day* (not needed in the same *meal*) in order to provide the body with *essential amino acids*.

Examples of plant foods' amino acid composition may be seen in the chart below:

Legumes—for example, soybean, black-eyed peas, pinto beans; good source of lysine poor source of (limited) tryptophan and sulfur-containing (S–C) amino acids (soybeans contain tryptophan)
Nuts–Seeds—for example, peanuts, sesame seeds; good source of tryptophan and S–C amino acids; poor source of lysine (peanuts contain less S–C amino acids)
Cereals–Grains (whole grains)—corn, rice, whole grains (Chap. 4); good source of tryptophan and S–C amino acids; poor source of lysine (corn is a poor source of tryptophan and good source of S–C amino acids; wheat germ is poor in tryptophan and S–C amino acids but a good source of lysine)

"Combining" (see above—combination of two or more complementary sources of incomplete proteins in order to provide a complete amino profile) may include serving beans with rice, tofu with vegetables on rice, black-eyed peas served with cornbread, tofu and cashews stir-fry, chick peas and sesame seeds (hummus) or peanut butter on whole wheat bread. As a common example, a vegetarian diet may frequently combine legumes (beans or peas) with either nuts–seeds or grains.

Mutual supplementation is the name given to this combination of two or more complementary sources of incomplete proteins in order to provide a complete amino profile. The requirement is that they are combined in a *day* (not needed in the same *meal*) in order to provide the body with *essential amino acids*.

CULINARY ALERT! Combine the appropriate incomplete proteins in order to create a complete protein.

Legumes

Legumes (Fig. 9.10) are the seeds of a pod of the *Leguminosae* family. The seed, found inside the pod, splits into two distinct parts attached to each other at the lower edge. They include edible peas that may be green, yellow, white, or variegated in color. They include sugar peas with edible pods, black-eyed peas, and more.

Legumes may exist as elongated, flattened, spherical, or kidney-shaped beans or peas. Notable are the edible, podded string beans/snap beans or green beans, kidney beans, or soybeans. Various beans, such as mung beans, are sprouted for culinary use, and others may be used for animal fodder. Frequently, legumes may be referred to as a pulse, and part of the bean, or pea family.

In addition to beans and peas, carob pods and lentils are legumes. Peanuts, despite their name, are *not* true nuts, however, legumes. They are the high protein seeds of a brown pod that appears contracted between the seeds (humped and inverted). Their ripening occurs underground.

Conspicuous changes occur in cooking legumes such as softening due to the gelatinization of starch and flavor improvement. The protein is coagulated and its availability is higher following cooking.

> Edible bean products contain both soluble and insoluble fiber which may help to slow digestion. These fibers can contribute to providing a feeling of fullness, or satiety, which can help in weight management . . . also contribute to a low glycemic index . . . a decreased level of glucose in blood following a meal. (Foster 2012)

Legumes may be the origin of intestinal distress and gas in some consumers. For that reason, an enzyme derived from *A. niger* has been processed for addition to foods such as these and is commercially available to consumers for their dietary use. As well, some individuals exhibit an *allergic* response with antibody production following ingestion of various legumes, thus Physicians and dietitians would recommend avoidance.

CULINARY ALERT! Beans and peas [along with cruciferous (cabbage family) vegetables and whole grains in the diet] are wholesome food choices recommended to many by physicians and dieticians for healthy eating. They are low in fat, contain no cholesterol, and are good sources of fiber.

Usually, soybeans are derived from an autumn harvest and are processed into oil, tofu, frozen dessert, “flour”, or textured vegetable protein.

- **Soybean oil**, pressed from the bean, is the highest volume vegetable oil in the United States and is commonly a constituent of margarine.
- **Tofu** is soy milk that has been coagulated to make the gel. Tofu is available in various types, ranging from soft to extra firm, depending on the water content. Extra firm tofu may be cut into small pieces and used in stir-fry cooking.
- **Frozen dessert** the curd is further processed and sweetened, it may be served as a frozen tofu- based dessert, similar to ice cream or ice milk. The soft tofu may be an ingredient of “shakes” or frozen, sweetened dessert mixtures.
- **Soy flour** is made of dehulled beans with the oil (that was 18 %) pressed out. It is useful by consumers who cannot consume wheat or flours with gluten-forming proteins. It is non-gluten. Although a soybean is not a

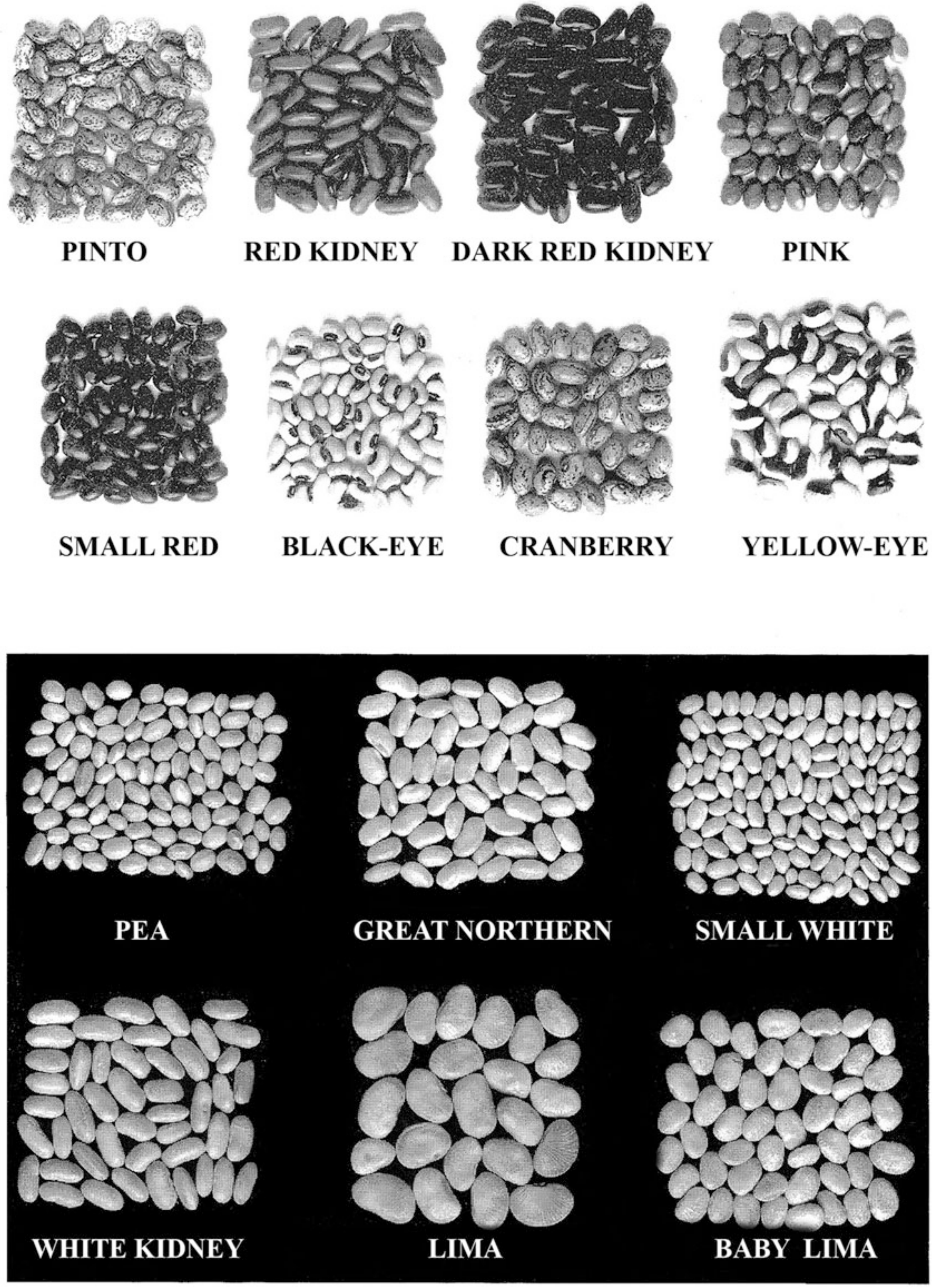


Fig. 9.10 Examples of some common legumes (*Source*: USDA)

cereal, it may be a source of "flour" in recipes.

- **Textured vegetable protein (TVP)** is used by food-service establishments, including school lunch programs that use soy protein on their menus. TVP may simulate a ground form of meat or meat flakes, it resembles the texture of meat, and is a good source of protein in meatless diets. It is the principal ingredient in artificial bacon sprinkles used for salads and other foods. In combination with colors, flavors, and egg binders (for ease of fabrication), the often-unpleasant characteristic flavor of soybeans can be covered.
- **Fermented soybeans** produce soy sauce, miso, and tempeh. Soy sauce is a combination of the fermented soy and wheat; miso is fermented soybean and/ or rice used in oriental sauces and soup bases. Tempeh is similar to tofu; however is inoculated with different bacteria.
  - A soy protein *concentrate* is soy that has been defatted, with soluble carbohydrate removed. It is *70 %* protein. An even higher quality soy ingredient may be manufactured using a soy protein isolate.
  - An *isolate* is *90 %* protein, with even more of the nonprotein material extracted, and with the addition of flavors and colors, it may be satisfactorily included in numerous foods. Nuts are addressed in the discussion of fruits and vegetables (Chap. 7).

Quorn as a Meat Alternative

Quorn (pronounced "kworn") is a meat alternative that became available to American consumers in early 2002 after being sold in Europe for over a decade. It is not a vegetable however, it is a fungus made into many meat-type products including patties and nuggets, and casseroles. A former FDA food safety chief (Sanford Miller, PhD.) and senior fellow at the Center for Food and Nutrition Policy states that "This product meets what the nutrition community thinks a product should be and in addition, it tastes good! Modern science can fabricate anything. We can imitate anything, but we always run into problems on how to have it taste good. Not taste alright, but taste good. This product does that."

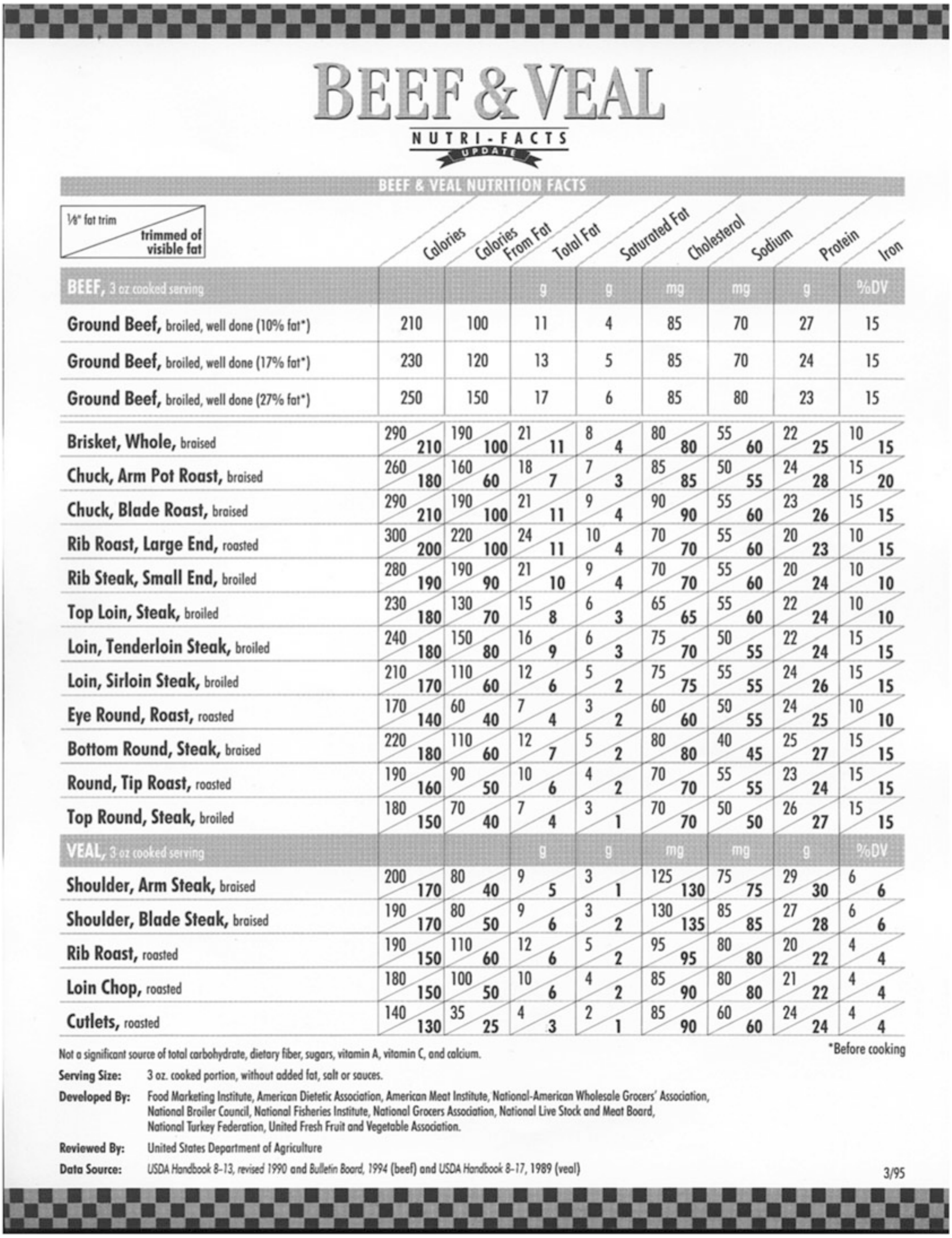
The mycoprotein was approved after undergoing a 5-year approval process with extensive animal and human testing. This process included a close look at possible allergens, which showed less than the allergens of mushrooms or soy (Peregrin 2002b).

According to an earlier report by the Center for Science in the Public Interest (CSPI), claims on some labels that the key ingredient in Quorn is "mushroom in origin," were not true. "Quorn products contain no mushrooms. Rather, the so-called "mycoprotein" in these products is actually grown in large fermentation vats from *Fusarium venenatum*, a non-mushroom fungus. On other Quorn packages, the source of mycoprotein is omitted altogether."

CSPI executive director Michael F. Jacobson said. "But Quorn's mycoprotein has nothing to do with mushrooms, plants, or vegetables. It is a fungus and should be labeled as such. Saying that Quorn's fungus is in the mushroom family is like saying that jellyfish are in the human family. If an obscure term like "mycoprotein" is to be used in Quorn's ingredient listings, says CSPI, packages should be required to disclose clearly the product's fungal origins." (CSPI)

Nutritive Value of Meat, Poultry, and Fish

Selected nutritive value aspects of meats (beef, veal, pork, and lamb), poultry (chicken and turkey), and fish and shellfish are shown in Figs. 9.11, 9.12, 9.13, and 9.14. These NutriFacts figures are the most recent ones reviewed by the USDA. Nutritive values for calories, calories



BEEF & VEAL

NUTRI-FACTS
UPDATE

BEEF & VEAL NUTRITION FACTS

¼" fat trim / trimmed of visible fat	Calories	Calories From Fat	Total Fat	Saturated Fat	Cholesterol	Sodium	Protein	Iron
BEEF, 3 oz cooked serving			g	g	mg	mg	g	%DV
Ground Beef, broiled, well done (10% fat*)	210	100	11	4	85	70	27	15
Ground Beef, broiled, well done (17% fat*)	230	120	13	5	85	70	24	15
Ground Beef, broiled, well done (27% fat*)	250	150	17	6	85	80	23	15
Brisket, Whole, braised	290 210	190 100	21 11	8 4	80 80	55 60	22 25	10 15
Chuck, Arm Pot Roast, braised	260 180	160 60	18 7	7 3	85 85	50 55	24 28	15 20
Chuck, Blade Roast, braised	290 210	190 100	21 11	9 4	90 90	55 60	23 26	15 15
Rib Roast, Large End, roasted	300 200	220 100	24 11	10 4	70 70	55 60	20 23	10 15
Rib Steak, Small End, broiled	280 190	190 90	21 10	9 4	70 70	55 60	20 24	10 10
Top Loin, Steak, broiled	230 180	130 70	15 8	6 3	65 65	55 60	22 24	10 10
Loin, Tenderloin Steak, broiled	240 180	150 80	16 9	6 3	75 70	50 55	22 24	15 15
Loin, Sirloin Steak, broiled	210 170	110 60	12 6	5 2	75 75	55 55	24 26	15 15
Eye Round, Roast, roasted	170 140	60 40	7 4	3 2	60 60	50 55	24 25	10 10
Bottom Round, Steak, braised	220 180	110 60	12 7	5 2	80 80	40 45	25 27	15 15
Round, Tip Roast, roasted	190 160	90 50	10 6	4 2	70 70	55 55	23 24	15 15
Top Round, Steak, broiled	180 150	70 40	7 4	3 1	70 70	50 50	26 27	15 15
VEAL, 3 oz cooked serving			g	g	mg	mg	g	%DV
Shoulder, Arm Steak, braised	200 170	80 40	9 5	3 1	125 130	75 75	29 30	6 6
Shoulder, Blade Steak, braised	190 170	80 50	9 6	3 2	130 135	85 85	27 28	6 6
Rib Roast, roasted	190 150	110 60	12 6	5 2	95 95	80 80	20 22	4 4
Loin Chop, roasted	180 150	100 50	10 6	4 2	85 90	80 80	21 22	4 4
Cutlets, roasted	140 130	35 25	4 3	2 1	85 90	60 60	24 24	4 4

Not a significant source of total carbohydrate, dietary fiber, sugars, vitamin A, vitamin C, and calcium.

*Before cooking

Serving Size: 3 oz. cooked portion, without added fat, salt or sauces.

Developed By: Food Marketing Institute, American Dietetic Association, American Meat Institute, National-American Wholesale Grocers' Association, National Broiler Council, National Fisheries Institute, National Grocers Association, National Live Stock and Meat Board, National Turkey Federation, United Fresh Fruit and Vegetable Association.

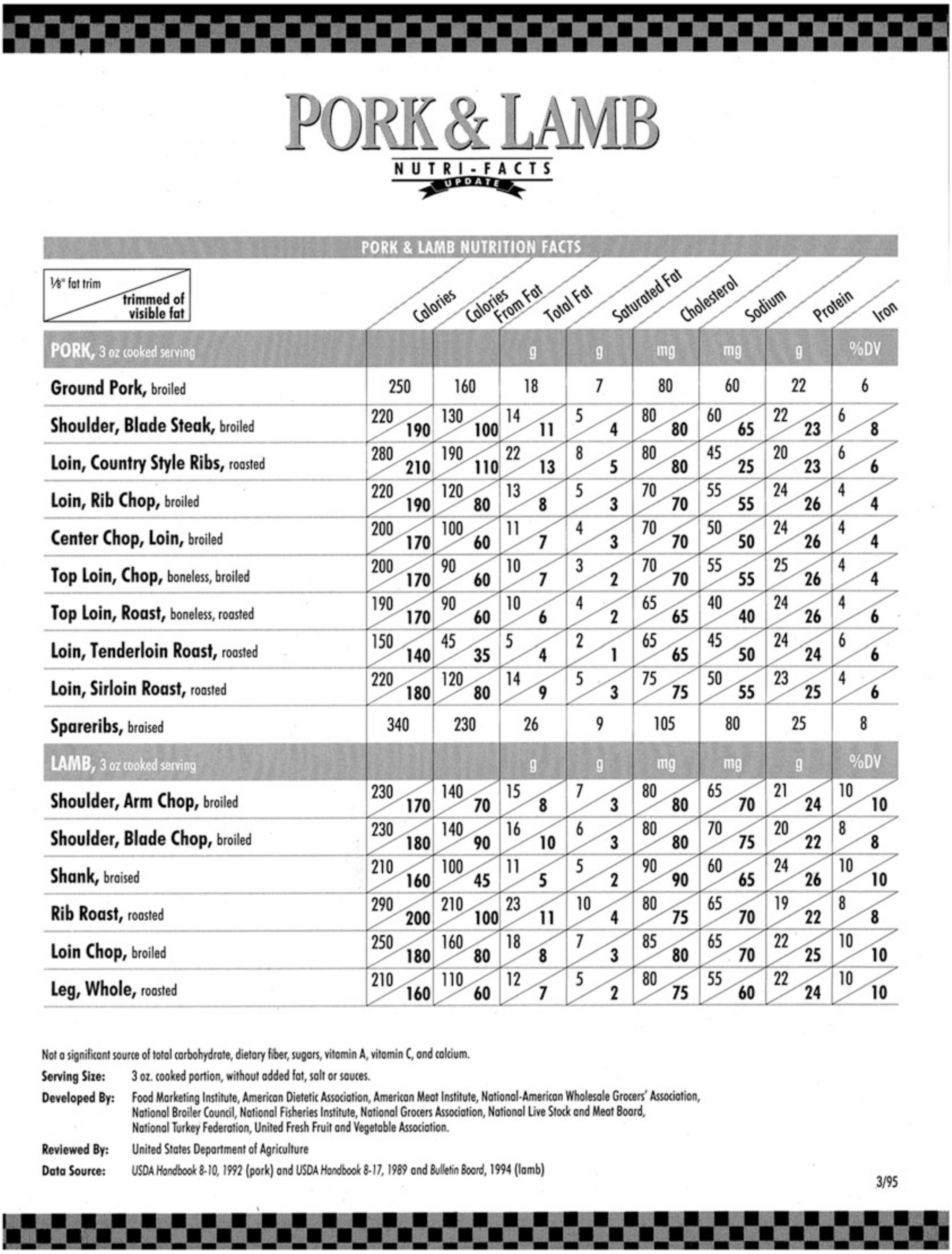
Reviewed By: United States Department of Agriculture

Data Source: *USDA Handbook 8-13, revised 1990* and *Bulletin Board, 1994* (beef) and *USDA Handbook 8-17*, 1989 (veal)

3/95

Fig. 9.11 Nutrifacts of beef and veal in 3-ounce cooked portions (*Source*: Food Marketing Institute)

from fat, total fat, saturated fat, cholesterol, sodium, protein, and iron are reported for beef and veal, pork and lamb, and chicken and turkey. Similarly, calories, calories from fat, total fat, saturated fat, cholesterol, sodium, potassium, total carbohydrate, protein, vitamin A, vitamin C, calcium, and iron are also reported for seafood.



PORK & LAMB

NUTRI-FACTS

UPDATE

PORK & LAMB NUTRITION FACTS

⅛" fat trim
trimmed of visible fat

	Calories	Calories From Fat	Total Fat	Saturated Fat	Cholesterol	Sodium	Protein	Iron
PORK, 3 oz cooked serving			g	g	mg	mg	g	%DV
Ground Pork, broiled	250	160	18	7	80	60	22	6
Shoulder, Blade Steak, broiled	220 190	130 100	14 11	5 4	80 80	60 65	22 23	6 8
Loin, Country Style Ribs, roasted	280 210	190 110	22 13	8 5	80 80	45 25	20 23	6 6
Loin, Rib Chop, broiled	220 190	120 80	13 8	5 3	70 70	55 55	24 26	4 4
Center Chop, Loin, broiled	200 170	100 60	11 7	4 3	70 70	50 50	24 26	4 4
Top Loin, Chop, boneless, broiled	200 170	90 60	10 7	3 2	70 70	55 55	25 26	4 4
Top Loin, Roast, boneless, roasted	190 170	90 60	10 6	4 2	65 65	40 40	24 26	4 6
Loin, Tenderloin Roast, roasted	150 140	45 35	5 4	2 1	65 65	45 50	24 24	6 6
Loin, Sirloin Roast, roasted	220 180	120 80	14 9	5 3	75 75	50 55	23 25	4 6
Spareribs, braised	340	230	26	9	105	80	25	8
LAMB, 3 oz cooked serving			g	g	mg	mg	g	%DV
Shoulder, Arm Chop, broiled	230 170	140 70	15 8	7 3	80 80	65 70	21 24	10 10
Shoulder, Blade Chop, broiled	230 180	140 90	16 10	6 3	80 80	70 75	20 22	8 8
Shank, braised	210 160	100 45	11 5	5 2	90 90	60 65	24 26	10 10
Rib Roast, roasted	290 200	210 100	23 11	10 4	80 75	65 70	19 22	8 8
Loin Chop, broiled	250 180	160 80	18 8	7 3	85 80	65 70	22 25	10 10
Leg, Whole, roasted	210 160	110 60	12 7	5 2	80 75	55 60	22 24	10 10

Not a significant source of total carbohydrate, dietary fiber, sugars, vitamin A, vitamin C, and calcium.

Serving Size: 3 oz. cooked portion, without added fat, salt or sauces.

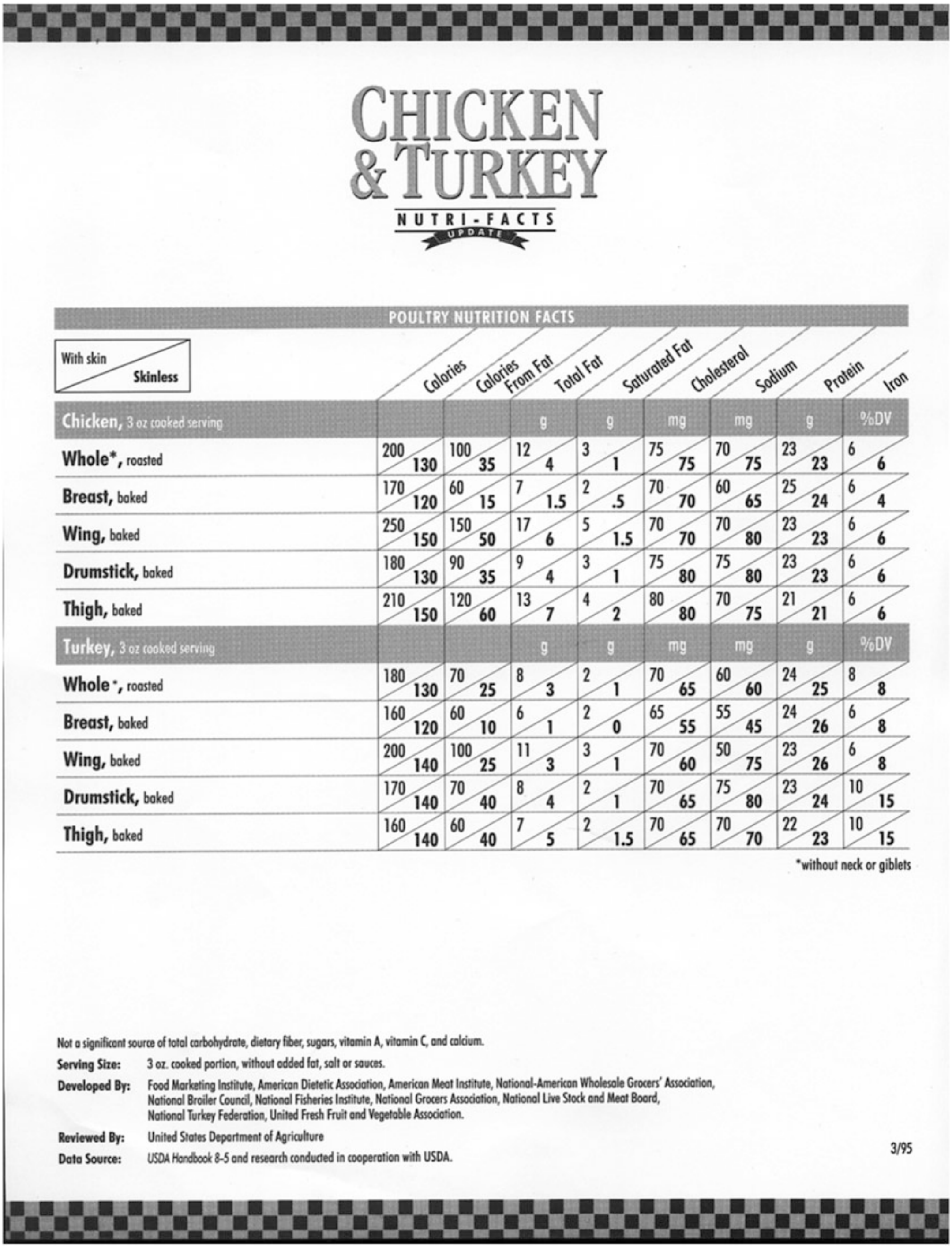
Developed By: Food Marketing Institute, American Dietetic Association, American Meat Institute, National-American Wholesale Grocers' Association, National Broiler Council, National Fisheries Institute, National Grocers Association, National Live Stock and Meat Board, National Turkey Federation, United Fresh Fruit and Vegetable Association.

Reviewed By: United States Department of Agriculture

Data Source: *USDA Handbook 8-10, 1992* (pork) and *USDA Handbook 8-17, 1989* and *Bulletin Board*, 1994 (lamb)

3/95

Fig. 9.12 Nutrifacts of pork and lamb in 3-ounce cooked portions (*Source*: Food Marketing Institute)



CHICKEN & TURKEY

NUTRI-FACTS
UPDATE

POULTRY NUTRITION FACTS

With skin / **Skinless**

	Calories	Calories From Fat	Total Fat	Saturated Fat	Cholesterol	Sodium	Protein	Iron
Chicken, 3 oz cooked serving			g	g	mg	mg	g	%DV
Whole*, roasted	200 **130**	100 **35**	12 **4**	3 **1**	75 **75**	70 **75**	23 **23**	6 **6**
Breast, baked	170 **120**	60 **15**	7 **1.5**	2 **.5**	70 **70**	60 **65**	25 **24**	6 **4**
Wing, baked	250 **150**	150 **50**	17 **6**	5 **1.5**	70 **70**	70 **80**	23 **23**	6 **6**
Drumstick, baked	180 **130**	90 **35**	9 **4**	3 **1**	75 **80**	75 **80**	23 **23**	6 **6**
Thigh, baked	210 **150**	120 **60**	13 **7**	4 **2**	80 **80**	70 **75**	21 **21**	6 **6**
Turkey, 3 oz cooked serving			g	g	mg	mg	g	%DV
Whole*, roasted	180 **130**	70 **25**	8 **3**	2 **1**	70 **65**	60 **60**	24 **25**	8 **8**
Breast, baked	160 **120**	60 **10**	6 **1**	2 **0**	65 **55**	55 **45**	24 **26**	6 **8**
Wing, baked	200 **140**	100 **25**	11 **3**	3 **1**	70 **60**	50 **75**	23 **26**	6 **8**
Drumstick, baked	170 **140**	70 **40**	8 **4**	2 **1**	70 **65**	75 **80**	23 **24**	10 **15**
Thigh, baked	160 **140**	60 **40**	7 **5**	2 **1.5**	70 **65**	70 **70**	22 **23**	10 **15**

*without neck or giblets

Not a significant source of total carbohydrate, dietary fiber, sugars, vitamin A, vitamin C, and calcium.

Serving Size: 3 oz. cooked portion, without added fat, salt or sauces.

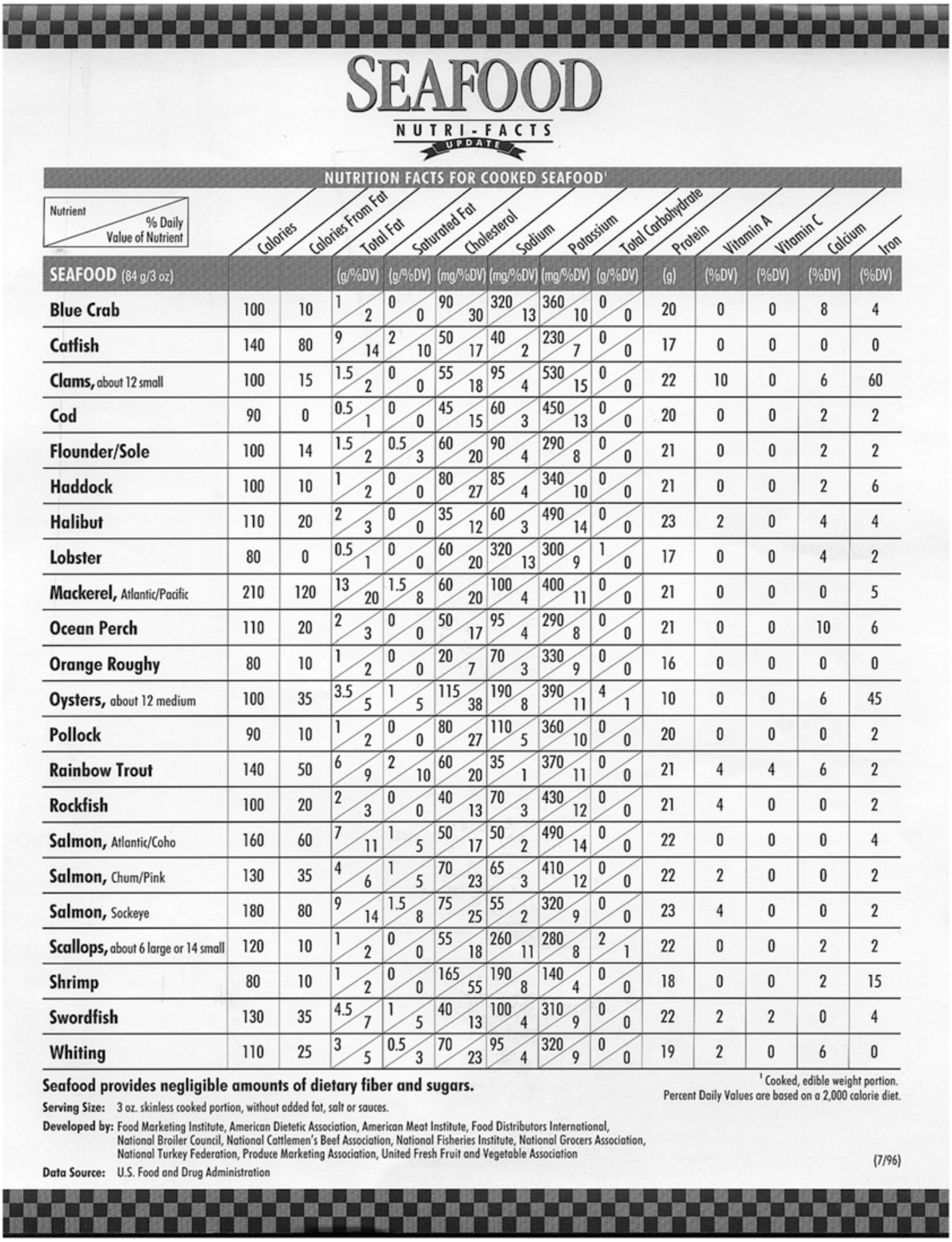
Developed By: Food Marketing Institute, American Dietetic Association, American Meat Institute, National-American Wholesale Grocers' Association, National Broiler Council, National Fisheries Institute, National Grocers Association, National Live Stock and Meat Board, National Turkey Federation, United Fresh Fruit and Vegetable Association.

Reviewed By: United States Department of Agriculture

Data Source: USDA Handbook 8-5 and research conducted in cooperation with USDA.

3/95

Fig. 9.13 Nutrifacts of chicken and turkey in 3-ounce cooked portions (*Source*: Food Marketing Institute)



SEAFOOD

NUTRI-FACTS

UPDATE

NUTRITION FACTS FOR COOKED SEAFOOD[1]

Nutrient / % Daily Value of Nutrient SEAFOOD (84 g/3 oz)	Calories	Calories From Fat	Total Fat (g/%DV)	Saturated Fat (g/%DV)	Cholesterol (mg/%DV)	Sodium (mg/%DV)	Potassium (mg/%DV)	Total Carbohydrate (g/%DV)	Protein (g)	Vitamin A (%DV)	Vitamin C (%DV)	Calcium (%DV)	Iron (%DV)
Blue Crab	100	10	1 / 2	0 / 0	90 / 30	320 / 13	360 / 10	0 / 0	20	0	0	8	4
Catfish	140	80	9 / 14	2 / 10	50 / 17	40 / 2	230 / 7	0 / 0	17	0	0	0	0
Clams, about 12 small	100	15	1.5 / 2	0 / 0	55 / 18	95 / 4	530 / 15	0 / 0	22	10	0	6	60
Cod	90	0	0.5 / 1	0 / 0	45 / 15	60 / 3	450 / 13	0 / 0	20	0	0	2	2
Flounder/Sole	100	14	1.5 / 2	0.5 / 3	60 / 20	90 / 4	290 / 8	0 / 0	21	0	0	2	2
Haddock	100	10	1 / 2	0 / 0	80 / 27	85 / 4	340 / 10	0 / 0	21	0	0	2	6
Halibut	110	20	2 / 3	0 / 0	35 / 12	60 / 3	490 / 14	0 / 0	23	2	0	4	4
Lobster	80	0	0.5 / 1	0 / 0	60 / 20	320 / 13	300 / 9	1 / 0	17	0	0	4	2
Mackerel, Atlantic/Pacific	210	120	13 / 20	1.5 / 8	60 / 20	100 / 4	400 / 11	0 / 0	21	0	0	0	5
Ocean Perch	110	20	2 / 3	0 / 0	50 / 17	95 / 4	290 / 8	0 / 0	21	0	0	10	6
Orange Roughy	80	10	1 / 2	0 / 0	20 / 7	70 / 3	330 / 9	0 / 0	16	0	0	0	0
Oysters, about 12 medium	100	35	3.5 / 5	1 / 5	115 / 38	190 / 8	390 / 11	4 / 1	10	0	0	6	45
Pollock	90	10	1 / 2	0 / 0	80 / 27	110 / 5	360 / 10	0 / 0	20	0	0	0	2
Rainbow Trout	140	50	6 / 9	2 / 10	60 / 20	35 / 1	370 / 11	0 / 0	21	4	4	6	2
Rockfish	100	20	2 / 3	0 / 0	40 / 13	70 / 3	430 / 12	0 / 0	21	4	0	0	2
Salmon, Atlantic/Coho	160	60	7 / 11	1 / 5	50 / 17	50 / 2	490 / 14	0 / 0	22	0	0	0	4
Salmon, Chum/Pink	130	35	4 / 6	1 / 5	70 / 23	65 / 3	410 / 12	0 / 0	22	2	0	0	2
Salmon, Sockeye	180	80	9 / 14	1.5 / 8	75 / 25	55 / 2	320 / 9	0 / 0	23	4	0	0	2
Scallops, about 6 large or 14 small	120	10	1 / 2	0 / 0	55 / 18	260 / 11	280 / 8	2 / 1	22	0	0	2	2
Shrimp	80	10	1 / 2	0 / 0	165 / 55	190 / 8	140 / 4	0 / 0	18	0	0	2	15
Swordfish	130	35	4.5 / 7	1 / 5	40 / 13	100 / 4	310 / 9	0 / 0	22	2	2	0	4
Whiting	110	25	3 / 5	0.5 / 3	70 / 23	95 / 4	320 / 9	0 / 0	19	2	0	6	0

Seafood provides negligible amounts of dietary fiber and sugars.

[1] Cooked, edible weight portion.
Percent Daily Values are based on a 2,000 calorie diet.

Serving Size: 3 oz. skinless cooked portion, without added fat, salt or sauces.

Developed by: Food Marketing Institute, American Dietetic Association, American Meat Institute, Food Distributors International, National Broiler Council, National Cattlemen's Beef Association, National Fisheries Institute, National Grocers Association, National Turkey Federation, Produce Marketing Association, United Fresh Fruit and Vegetable Association

Data Source: U.S. Food and Drug Administration

(7/96)

Fig. 9.14 Nutrifacts of seafood in 3-ounce cooked portions (*Source*: Food Marketing Institute)

Meats are excellent sources of complete protein, many B vitamins, including B_{12} that is only found in animal products, and also the minerals iron and zinc. For additional information on the nutritive value of meat and its many vitamins and minerals, the reader is referred to Figs. 9.11, 9.12, 9.13, and 9.14 that follow as well as other nutrition textbooks.

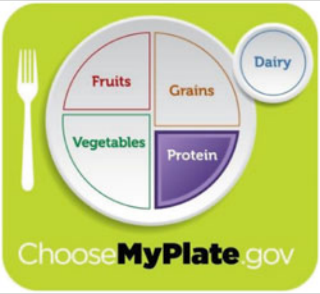
"Most health and nutrition authorities believe the majority of Americans consume too much sodium." . . . The CDC "believes that if manufacturers of the top-10 categories of food responsible for 44 % of people's sodium intake were to reduce the sodium content of these foods by 25 %, they could help prevent an estimated 28,000 deaths annually. With CDC having identified cold cured cuts and cured meats as well as fresh and processed poultry as two of the top-10 categories, processed-meat manufacturers stepping up to the challenge (Berry 2013)".

In 2000, The American Heart Association announced the organization's official recommendation for daily consumption of soy protein. Soybeans have antioxidant properties and contain saponins noted for their disease-fighting potential.

What Foods Are in the Protein Foods Group?

All foods made from meat, poultry, seafood, beans and peas, eggs, processed soy products, nuts, and seeds are considered part of the Protein Foods Group. Beans and peas are also part of the Vegetable Group. For more information on beans and peas, see Beans and Peas Are Unique Foods.

Select a variety of protein foods to improve nutrient intake and health benefits, including at least 8 ounces of cooked seafood per week. Young children need less, depending on their age and calorie needs. The advice to consume seafood does not apply to vegetarians. Vegetarian options in the Protein Foods Group include beans and peas, processed soy products, and nuts and seeds. Meat and poultry choices should be lean or low-fat.



Grains Group	Vegetable Group	Fruit Group	Dairy Group	Protein Foods Group
Make at least half your grains whole.	Vary your veggies.	Focus on fruits.	Get your calcium-rich foods.	Go lean with protein.

All foods made from meat, poultry, seafood, beans and peas, eggs, processed soy products, nuts, and seeds are considered part of the Protein Foods Group. Beans and peas are also part of the Vegetable Group. For more information on beans

10 tips
Nutrition Education Series

healthy eating for vegetarians

10 tips for vegetarians

ChooseMyPlate.gov

A vegetarian eating pattern can be a healthy option. The key is to consume a variety of foods and the right amount of foods to meet your calorie and nutrient needs.

1 think about protein

Your protein needs can easily be met by eating a variety of plant foods. Sources of protein for vegetarians include beans and peas, nuts, and soy products (such as tofu, tempeh). Lacto-ovo vegetarians also get protein from eggs and dairy foods.

2 bone up on sources of calcium

Calcium is used for building bones and teeth. Some vegetarians consume dairy products, which are excellent sources of calcium. Other sources of calcium for vegetarians include calcium-fortified soymilk (soy beverage), tofu made with calcium sulfate, calcium-fortified breakfast cereals and orange juice, and some dark-green leafy vegetables (collard, turnip, and mustard greens; and bok choy).

3 make simple changes

Many popular main dishes are or can be vegetarian—such as pasta primavera, pasta with marinara or pesto sauce, veggie pizza, vegetable lasagna, tofu-vegetable stir-fry, and bean burritos.

4 enjoy a cookout

For barbecues, try veggie or soy burgers, soy hot dogs, marinated tofu or tempeh, and fruit kabobs. Grilled veggies are great, too!

5 include beans and peas

Because of their high nutrient content, consuming beans and peas is recommended for everyone, vegetarians and non-vegetarians alike. Enjoy some vegetarian chili, three bean salad, or split pea soup. Make a hummus-filled pita sandwich.

6 try different veggie versions

A variety of vegetarian products look—and may taste—like their non-vegetarian counterparts but are usually lower in saturated fat and contain no cholesterol. For breakfast, try soy-based sausage patties or links. For dinner, rather than hamburgers, try bean burgers or falafel (chickpea patties).

7 make some small changes at restaurants

Most restaurants can make vegetarian modifications to menu items by substituting meatless sauces or non-meat items, such as tofu and beans for meat, and adding vegetables or pasta in place of meat. Ask about available vegetarian options.

8 nuts make great snacks

Choose unsalted nuts as a snack and use them in salads or main dishes. Add almonds, walnuts, or pecans instead of cheese or meat to a green salad.

9 get your vitamin B_{12}

Vitamin B_{12} is naturally found only in animal products. Vegetarians should choose fortified foods such as cereals or soy products, or take a vitamin B_{12} supplement if they do not consume any animal products. Check the Nutrition Facts label for vitamin B_{12} in fortified products.

10 find a vegetarian pattern for you

Go to www.dietaryguidelines.gov and check appendices 8 and 9 of the *Dietary Guidelines for Americans, 2010* for vegetarian adaptations of the USDA food patterns at 12 calorie levels.

USDA United States
Department of Agriculture
Center for Nutrition
Policy and Promotion

Go to www.ChooseMyPlate.gov for more information.

DG TipSheet No. 8
June 2011

and peas, see Beans and Peas Are Unique Foods.

Select a variety of protein foods to improve nutrient intake and health benefits, including at least 8 ounces of cooked seafood per week. Young children need less, depending on their age and calorie needs. The advice to consume seafood does not apply to vegetarians. Vegetarian options in the Protein Foods Group include beans and peas, processed soy products, and nuts and seeds. Meat and poultry choices should be lean or low-fat.

Key consumer message: Go lean with protein View Protein Food Gallery

A nutrition article on the Paleo Diet is not limited to a discussion on red meat, yet is included in this meat chapter.

The Paleo Diet

Should We Eat Like Our Caveman Ancestors?

By Lauren Innocenzi

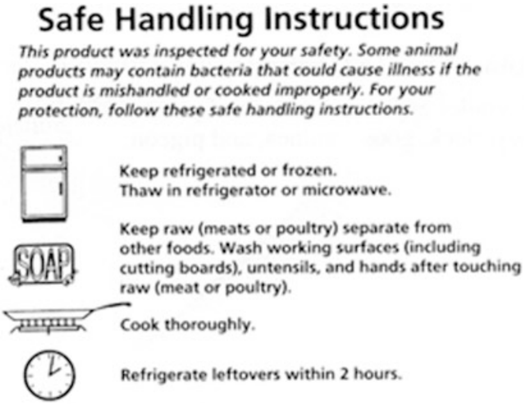
"The Paleolithic (Paleo) diet, also called the "Caveman" or "Stone Age" diet, centers around the idea that if we eat like our ancestors did 10,000 years ago, we'll be healthier, lose weight and curb disease. "A quick and pithy definition of the Paleo diet is—if the cavemen didn't eat it then you shouldn't either," says Academy Spokesperson Jim White, RD, ACSM/HFS. That means foods that can be hunted, fished or gathered: meat, fish, shellfish, poultry, eggs, veggies, roots, fruits, and berries. No grains, no dairy, no legumes (beans or peas), no sugar, no salt. Why? "According to proponents, our bodies are genetically predisposed to eat this way. They blame the agricultural revolution and the addition of grains, legumes and dairy to the human diet for the onset of chronic disease (obesity, heart disease, and diabetes)," says White.

On one hand, this way of eating encourages including more fruits and vegetables and cutting out added sugar and sodium—which aligns with the 2010 *Dietary Guidelines for Americans*. The combination of plant foods and a diet rich in protein can help control blood sugar, regulate blood pressure, contribute to weight loss and prevent Type 2 diabetes, says White.

But a typical plan also exceeds the *Dietary Guidelines* for daily fat and protein intake and falls short on carbohydrate recommendations, according to a review from *US News & World Report*. The exclusion of whole grains, legumes, and dairy can be risky as well. "These foods are nutrient-rich and contain important vitamins and minerals such as calcium and vitamin D. Without these foods, supplementation is necessary," says White. "Eating this way . . . can be very healthy but the lack of certain foods may result in certain deficiencies."

Eliminating whole grains and dairy is not necessarily the ticket to ending disease and ensuring weight loss. Whole grains contain dietary fiber, which may help reduce your risk of heart disease, cancer and diabetes, and other health complications. And studies suggest that dairy may play a role in weight loss. "The crux of the problem, with respect to grains and dairy, stem from over consumption, and as with anything, excess quantities will become problematic," explains White.

The Paleo diet might also be hard to sustain. "We live in a society where it is not possible to eat exactly as our ancestors ate. For example, wild game is not readily available as most of the meat we consume has been domesticated. And the plant food we eat has also been processed rather than grown and gathered in the wild," says White. "While strict conformity is not realistic, it is possible to modify the plan, eating only wild caught fish, grass-fed meat, and organic fruits and vegetables." But even that can be hard to follow because of lack of variety, need for planning, supplementation, and cost, White adds.



Safe Handling Instructions

This product was inspected for your safety. Some animal products may contain bacteria that could cause illness if the product is mishandled or cooked improperly. For your protection, follow these safe handling instructions.

Keep refrigerated or frozen. Thaw in refrigerator or microwave.

Keep raw (meats or poultry) separate from other foods. Wash working surfaces (including cutting boards), untensils, and hands after touching raw (meat or poultry).

Cook thoroughly.

Refrigerate leftovers within 2 hours.

Fig. 9.15 Safe handling instructions

Lauren Innocenzi is an online content manager for the Academy of Nutrition and Dietetics.

Safety of Meat, Poultry, and Fish

The safety of meat, poultry, and fish is of utmost concern. Meat is a potentially hazardous food that supports rapid bacterial growth if contaminated and then stored at improper temperatures (Chap. 16). Because all meat contains bacteria, it should be maintained in a clean and covered condition, at temperatures that retard the growth of microorganisms which may both contaminate and spoil meat, producing changes in the color, odor, and safety. *Safe handling* instructions appearing on meat packages is shown in Fig. 9.15.

A former USDA deputy undersecretary of food safety has said "We are strongly encouraging specific interventions for raw meat and poultry in order to further reduce the level and incidence of pathogens such as *Salmonella* in these products. We feel that there is a whole arsenal of potentially effective interventions that could be utilized" (CDC).

Regarding irradiation to control pathogens, according to the USDA, "If irradiated meat is used in another product, such as pork sausage, then the ingredients statement must list irradiated pork, but the radura does not have to appear on the package."

Restaurants are not required to disclose the use of irradiated products to their customers; however, some restaurants voluntarily provide irradiation information on menus.

How should I handle irradiated meat and poultry?

Food irradiation is not a substitute for good sanitation and does not replace safe cooking and handling. Consumers should handle irradiated foods just like any other food and always follow safe food handling practices.

"Food irradiation is a technology for controlling spoilage and eliminating foodborne pathogens. The result is similar to pasteurization. The fundamental difference between food irradiation and pasteurization is the source of the energy used to destroy the microbes. While conventional pasteurization relies on heat, irradiation relies on the energy of ionizing radiation."

Table 9.1 Minimum safe internal temperature for selected meats

Meat	Temperature
Beef steaks (rare)	155 °F (68 °C) (upon consumer order)
Roast beef (rare)	130 °F (54 °C) (time dependent)
Pork	155 °F (68 °C) or 170 °F (77 °C) in a microwave oven
Ground beef	155 °F (68 °C)
Poultry	165 °F (74 °C)

Source: FDA

Check your steps at FoodSafety.gov. Also see Chap. 19.

- **CLEAN.** Wash hands and surfaces often.
- **SEPARATE.** Separate raw meats from other foods.
- **COOK.** Cook food to the right temperature.
- **CHILL.** Refrigerate food promptly.

CULINARY ALERT! Adherence to specific temperatures is necessary for the prevention of growth and the destruction of harmful microorganisms in meat. Adequate refrigeration, cooking, and holding, as well as reheating are all important in controlling bacteria. Personal hygiene and sanitation are also important in preventing the spread of bacteria.

The bacteria, *Clostridium botulinum,* is an *anaerobic* bacteria that causes the disease botulism. It is a deadly form of food poisoning that may result from consuming improperly processed canned or vacuum-packed meats. To control this, nitrite may be added to processed meat to inhibit the reproduction of bacterial spores.

A more widespread, less deadly bacteria such as *Staphylococcus aureus* may grow in contaminated meat products. Subsequently the bacteria may be destroyed in cooking; however, the toxin that the bacteria secretes survives cooking and may cause food illness in as little as one hour after consumption of contaminated meat.

Additional bacteria and agents are problematic as well. Poultry without sufficient cooking may contain the live, infection-causing *Salmonella* bacteria, which is the most common cause of foodborne infections in the United States. Most *Salmonella* are destroyed at 161 °F (72 °C) for 16 s, or 143 °F (62 °C) for 30 min. Another Clostridium, *Clostridium perfringens*, is found in meats especially those that were allowed to cool slowly following cooking. Undercooked pork may contain the parasite *Trichinella spiralis*, which is killed at temperatures of 155 °F (68 °C).

Ground beef, the *combined* meat from *many* cattle, is more likely to have contamination with *E. coli 0157:H7* than is a *single* cut of meat (such as steak) coming from a *single* animal. Bacteria may spread during processing and handling, and then cooking temperatures of 155 °F (68 °C) are necessary to destroy any E. coli that might be in the meat. A major challenge to the safety of ready-to-eat (r.t.e.) products includes *Listeria monocytogenes*. This may grow under refrigeration, yet is destroyed by thermal processing.

The USDA gave approval for *steam pasteurization* as an antimicrobial treatment of beef carcasses (see below). This treatment reduces the risk of *E. coli 0157:H7* by exposing the entire surface of the carcass to steam that kills the bacteria. Meat processors must avoid subsequent recontamination of the product, and the consumer must handle the meat with care. The use of steam pasteurization for *pork and poultry* is subject to further research.

The American Meat Institute Foundation (AMIF) speaks for the industry in saying that it *sanitizes* fresh meat, as well as the r.t.e meat products, including hams, and hot dogs. This sanitization is achieved either by steam pasteurization, which (1) exposes the carcass to a steam filled cabinet, or (2) uses of a handheld device in steam vacuuming, whereby steam is sprayed directly onto carcass spots where contamination is suspected. With the added food protection provided by the uses of multiple intervention strategies, sprays and organic acid (lactic and acetic acids) and hot water treatment are also used widely (Mermelstein 2000).

Further FDA-approved treatments include high-intensity pulsed-light treatment for the control of microorganisms on the surface of food (61 FR42381-42382). Irradiation is a process often used to destroy the pathogens that are present in meat and extend refrigerator shelf life. The FDA has approved *radiation* of fresh, frozen meats.

A US patent has been awarded to a company that uses electricity as the energy source to pasteurize processed and packaged foods, including r.t.e. meats such as hot dogs and luncheon meats (Food Eng 2000). The use of *ozone* to disinfect poultry processing water is reviewed on a case-by-case basis.

CULINARY ALERT! Meat must be kept safe in the defrosting process. The FDA advises thawing below temperatures of 45 °F (7 °C), under cold, running water, or by microwave, if immediately cooked. Slow thawing, with intact wrappers, is the defrosting method that allows the least moisture loss. The USDA recommends refreezing only in the case of properly thawed and cooked meats.

The FDA-recommended cooking temperatures to control bacterial growth and prevent foodborne illness are listed in Table 9.1 (check local jurisdiction).

Concern exists over *Bovine Spongiform Encephalopathy* (BSE) or "*Mad Cow Disease*." Further understanding of the disease and vigilance is needed to protect the food supply.

At this time, "meat recalls are down and safety is up" according to the data from the CDC (Decker 2012). The usual suspects include *E. coli 0157:H7* in beef and dairy cattle, *Salmonella* and *Campylobacter* in swine and poultry, *Listeria monocytogenes* in r-t-e foods. As well, *staphylococcus aureus* is a common contaminant. "... ground products may have pathogens spread throughout the product", so ordering a 'rare" burger may pose risk.

Handling the foods properly is also a priority, as it is reported "ultimately, the riskiest meat product is the one that's not handled properly, but is abusively stored, handled or undercooked, allowing pathogens to be transmitted to the consumer."(Decker 2012)

Reported by the Meat Science Department at a leading university,

> While not all lessons are easily learned, and some might come at great costs, the meat and poultry industries have actively updated their practices with new information as it has become available. (Decker 2012)

Also of current concern is the unique disease known as Alpha-Gal or *galactose alpha 1,3-galactose*. In this disease, an *IgE antibody* binds onto the *carbohydrate* present in mammal meat *galactose-alpha 1,3-galactose*. Affected persons eating this carbohydrate (not a protein) in meat show a *delayed anaphylaxis* response of several hours, instead of the typical minutes.

Mammalian products including beef, pork, lamb, rabbit, goat, or deer meat cause this disease. Alpha-Gal is *not* found in the nonmammalian poultry or fish.

It may be noted that previous tick bites in an individual trigger this reaction (tiny ticks are often known as chiggers).

Conclusion

Meat is the edible portion of animals used for food. Beef, pork, lamb, and veal are included in the definition of meat, and other animal products such as poultry and fish are commonly considered to be "meats". The amount and type of meat consumption varies throughout the world. Meat is primarily a muscle tissue and also contains connective tissue with a greater variance in the amount of adipose tissue held inside. Water is present to a greater degree in lean meats and young animals. The protein is a complete protein and contains all the essential amino acids.

Cuts of meat include primal or wholesale, subprimal, and retail cuts, with the latter being more familiar to consumers, as it is what they may purchase at their grocery market. The inherent tenderness of a particular cut depends on such factors as location on the carcass, postmortem changes in the muscle, including the stage of rigor mortis, aging, and the method of cooking. Meat color such as red or white, or "dark meat" is dependent on myoglobin and hemoglobin pigments. Changes in the color of meat may result from exposure to oxygen, acidity, and light.

Meat is subject to inspections and grading in order to provide the consumer with safe, more consistent, and reliable meat products. Meat is a potentially hazardous food and adherence to specific temperatures (cold and hot) is necessary for the prevention of growth and the destruction of harmful microorganisms.

Cooking meat causes the uncoiling or denaturation of peptide protein chains to occur. Tender cuts of meat remain tender when cooked by dry heat for a short time at high temperatures. Overcooking tender cuts of meat produces tough, dry meat, because water is released during denaturation. Less tender cuts of meat become increasingly tender as collagen solubilizes during lengthy exposure to moist heat cooking.

Beef, veal, pork, and lamb may be altered by various processing methods. This includes restructuring, and artificial tenderizing. Ham, corned beef, and bacon are examples of cured meat. Beef, ham, and turkey may be smoked to impart flavor and offer microbial control by dehydration. An alteration to meat occurs as meat is artificially tenderized and includes mechanical, electrical, and enzymatic treatment.

Poultry makes a significant contribution to the US diet and is classified according to age and condition of the bird. Many processed poultry products, including ground turkey, lunchmeats, and formed entrees, are available for use by consumers. Edible fish and shellfish including restructured fish such as surimi provide high-quality protein food to the diet.

Various legumes are consumed. They are incomplete proteins and when eaten in combination according to amino acid profiles, they form a complete protein and function as meat alternatives.

Make informed choices of your protein selection!

Notes

CULINARY ALERT!

Glossary

Actin The protein of muscle that is contained in the thin myofilaments and is active in muscle contraction.

Actomyosin The compound of actin and myosin that forms in muscle contraction.

Adipose tissue Fatty tissue; energy storage area in an animal.

Aging Process in which muscles become more tender due to protein breakdown.

Collagen Connective tissue protein; the largest component that gives strength to connective tissue; is solubilized to gelatin with cooking.

Connective tissue The component of animal tissue that extends beyond the muscle fibers to form tendons which attach the muscle to bones; it connects bone to bone; endomysium, perimysium, and epimysium connective tissue surrounds muscle fibers, muscle bundles, and whole muscles, respectively.

Cured meat Contains nitrite to form the pink color and control the growth of *Clostridium botulinum.*

Dry heat Method of cooking tender cuts of meat, including broiling, frying, pan-frying, and roasting.

Elastin Connective tissue protein; the yellow component of connective tissue that holds bone and cartilage together.

Endomysium Connective tissue layer that surrounds individual muscle fibers.

Epimysium Connective tissue layer that surrounds an entire muscle.

Gelatin Formed from the tenderization of collagen, used for edible gels in the human diet.

Grain Primary bundle containing 20–40 muscle fibrils.

Halal “Proper and permitted” food under jurisdiction of trained Muslim inspection.

Kosher “Fit and proper” or “properly prepared” food under jurisdiction of the Jewish faith; following the Mosaic or Talmudic Law.

Marbled Intermuscular and intramuscular fatty tissue distributed in meat.

Moist heat Method of cooking less tender cuts of meat, including braising, pressure-cooking, simmering, or stewing.

Muscle tissue The lean tissue of meat.

Myofibril The contractile actin and myosin elements of a muscle cell.

Myosin Protein of a muscle contained in the thick myofilaments that reacts with actin to form actomyosin.

Perimysium The connective tissue layer that surrounds muscle bundles.

Primal cut Wholesale cut of meat; it contains the subprimal and retail cuts.

Retail cut Cuts of meat available in the retail market; cut from primal cuts.

Reticulin Minor connective tissue found in younger animals; it may be the precursor of collagen or elastin.

Rigor mortis Postmortem state 6–24 h after death in which muscles stiffen and become less extensible; onset of rigor mortis correlates with depletion of ATP in the slaughtered animal.

Sarcomere Repeating unit of the muscle myofibrils.

Sarcoplasmic protein The hemoglobin and myoglobin pigments, and enzymes in the cytoplasm of a muscle fiber.

Smoked meat Meat that has been treated to impart flavor by exposure to aromatic smoke of hardwood; smoking preserves by dehydrating, thus offering microbial control.

Stromal protein Proteins including collagen, elastin, and reticulin of the connective tissue and supporting framework of an animal organ.

Subprimal cut Division of a primal cut.

Wholesome Inspection does not indicate the presence of illness.

Z-lines Boundaries of the sarcomere; holds thin filaments in place in the myofibril.

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TX A&M University. Meat Science Dept

Uniform Retail Meat Identity Standards (URMIS)

USDA Choosemyplate

USDA's Meat and Poultry Hotline (1-800-535-4555), Food Safety and Inspection Service, Washington, DC. For more information on food irradiation and other food safety issues, contact USDA's Meat and Poultry Hotline at 1-888-MPHotline (1-888-674-6854) or visit www.fsis.usda.gov

Vegetarian nutrition—http://fnic.nal.usda.gov/lifecycle-nutrition/vegetarian-nutrition Food and Nutrition Information Center (FNIC)

National Agricultural Library (NAL). http://www.nal.usda.gov/fnic/pubs/bibs/gen/vegetarian.pdf

10

Eggs and Egg Products

Introduction

The eggs of various birds are consumed throughout the world; however, the discussion that follows in this chapter is regarding *hen* eggs. Eggs are a natural biological structure with shells offering protection for developing chick embryos. They have numerous functions in food systems and must be protected against becoming or offering contamination. Eggs provide nutritive value and culinary variety to the diet, while being an economical source of food. Today, we see a reversal of dietary limitations, and healthy persons can enjoy eggs as long as they form part of a healthy, balanced diet.

Eggs are considered by the World Health Organization (WHO) to be the reference protein worldwide, to which all other protein is compared. A vegetarian diet that includes eggs is an ovo-vegetarian diet.

The quality and freshness of eggs is important to regulatory agencies, processors, and consumers, and is determined by a number of factors. The age, temperature, humidity, and handling of eggs determine freshness. Egg safety is significant.

Physical Structure and Composition of Eggs

The Whole Egg

An average hen egg weighs about 2 ounces (57 g), which includes the weight of the yolk, white, and shell. Each component differs in composition as shown in Tables 10.1 and 10.2. See structure of a hen's egg, Fig. 10.1 (California Egg Commission, Upland, CA).

CULINARY ALERT! Egg protein includes the enzyme *alpha-amylase*. This enzyme must be inactivated by heat in order to have desirable cooked egg mixtures. Undercooked egg mixtures may not show a deleterious effect until after the egg has been refrigerated.

The Yolk

An egg yolk comprises approximately 31 % of the weight of an egg, *all* of the egg's cholesterol, and almost all of the fat. Generally, it has a *higher* nutrient density than the white, containing all of the vitamins known, except vitamin C.

V.A. Vaclavik and E.W. Christian, *Essentials of Food Science, 4th Edition*, Food Science Text Series,
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Table 10.1 Chemical composition of the hen's egg by percentage

Component	%	Water	Protein	Fat	Ash
Whole egg	100	65.5	11.8	11.0	11.7
Egg white	58	88.0	11.0	0.2	0.8
Egg yolk	31	48.0	17.5	32.5	2.0
Shell	11				

Source: USDA

Table 10.2 Protein and fat content of egg components in grams

Component	Protein	Fat
Whole egg	6.5	5.8
Egg white	3.6	—
Egg yolk	2.7	5.2

Source: USDA

Additionally, yolks supply flavor and mouthfeel that consumers find acceptable; they have many culinary uses.

A cluster of developing yolks, each within its own sac, is present in the hen ovary.

Egg yolks contain all three *lipids*—triglycerides—fats and oils, phospholipids, and sterols in large spheres, granules, and micelles. The primary phospholipid is phosphatidyl choline, or *lecithin*; the most well known sterol is *cholesterol* found in the yolk.

Protein in the yolk represents 40 % of the eggs protein. Primarily vitellin is present in a lipoprotein complex as lipovitellin and lipovitellinin. The phosphorus-containing phosvitin and sulfur-containing livetin are also present in yolks. Scientists measure dietary protein quality by (1) its amino acid composition—quality and quantity, and (2) its digestibility—how well the human body absorbs and uses the ingested protein. Eggs are often used as the "gold standard" for measuring the protein quality of other foods (see PDCAAS).

The yolk *pigments*—mainly xanthophylls, also carotene and lycopene—come from animal feed such as the green plants and yellow corn that the hen eats. If yolks have a higher carotenoid content, they are *darker* (although not necessarily of vitamin A potential); however, chickens producing eggs with *pale* yolks may be fed supplements that darken the yolk. Concentric rings of slightly different colors appear in the yolk, beginning in the center with a very small white spot. Green color of boiled eggs is discussed later.

There is a higher concentration of *solids* in the yolk than in the white, and thus water movement into the yolk occurs as the egg ages. This water movement causes the egg yolks enlarge and become less viscous.

Surrounding the yolk is a colorless sac, the **vitelline membrane** (Fig. 10.1). It is continuous with the opaque-colored chalazae (kah-lay-za) cord structure. The chalazae is a ropelike cord that attaches to the yolk vitelline membrane yet is actually found in the albumen, or white. It holds the yolk in place at the center of the egg, preventing it from the damaging effects of hitting the shell (similar to a bungi jumping cord!).

The White

The egg white, also known as the **albumen** (Fig. 10.1), comprises approximately 58 % of the weight of an egg. As with the yolk, the white too consists of concentric layers. There are four layers - two thick and two thin whites separated by inner and outer thin whites. In lower grade or older eggs, the thick albumen becomes *indistinguishable* from the thin whites. The chalazae is located within these layers of the albumen and is continuous with the vitelline membrane that surrounds the yolk. A fresh egg has a more prominent chalazae than older eggs.

Eggs contain a high biological value protein, which is a *complete* protein, with all of the essential amino acids in a well-balanced proportion. Over half of the protein in whites is *ovalbumin*, although conalbumin, ovomucid, and globulins (including lysozyme, which is able to lyse some bacteria) contribute lesser percentages of protein in the egg whites. Whites provide *more* protein than the yolk and are often cooked and eaten alone, or incorporated into a recipe. The addition of egg whites in place of an entire egg adds protein while limiting fat and cholesterol. Avidin is another egg white protein. If consumed *raw*,

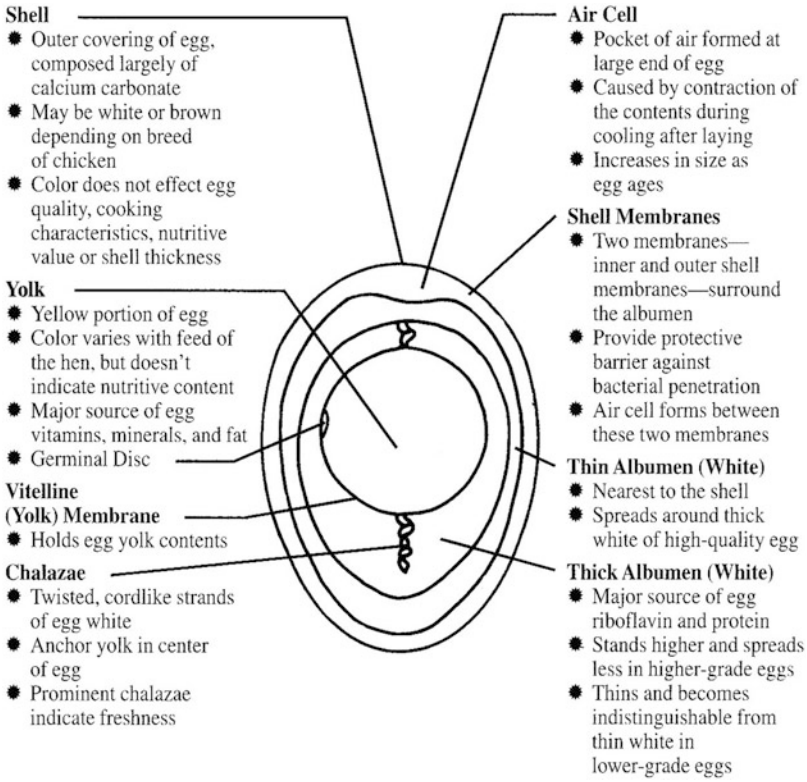


Fig. 10.1 Structure of a hen's egg (*Source*: California Egg Commission

the avidin binds with the vitamin biotin and renders biotin ineffective when consumed. Approximately 60 % of egg protein is located in the egg white.

Egg white proteins attach themselves to the yolk as it descends down the oviduct of the hen. Other constituents of the white are a negligible amount of fat; the vitamins riboflavin (which imparts a greenish tint to the white), niacin, biotin; and minerals including magnesium and potassium.

The Shell

The shell contributes the remaining 11 % weight of the whole egg. The dry shell contains the following:

- 94 % Calcium carbonate
- 1 % Magnesium carbonate
- 1 % Calcium phosphate
- 4 % Organic matrix made primarily of protein

Layers of the shell consist of a *mammillary* or inner layer, a *spongy* layer, and the outer *cuticle* (which may erroneously be referred to as "bloom"). The cuticle blocks the pores and protects the egg against outside contamination entering the egg.

Thousands of pores run throughout these layers of the shell, with a greater number at the large end. A shell is *naturally* porous for a potentially developing chick inside. As a result of the pores, CO_2 and moisture losses occur and O_2 enters the shell. The shell also functions as a barrier against harmful bacteria and mold entry, as a protein layer of keratin partially seals the shell pores.

"Sweating" or moisture condensation on the shell may produce stains. The presence of animal droppings may also stain. However, simply washing is *not* recommended as it may remove the shell's outer cuticle lining or open its pores resulting in a diminished shelf life. Once the outside protection is violated, microorganisms from the outside can travel to the inside contents and contaminate the egg.

Two thin shell *membranes* (Fig. 10.1) are inside of the shell, *one* of which is attached to the shell, and the *other* is not attached, but rather, moves with the egg contents. The air cell (discussed later) develops as the two membranes separate at the large end of the egg.

Color

The color of both the *shell* and *yolk* will be addressed in this section. *Egg shell color* depends on the *breed* of hen and has *no* known effect on egg flavor or quality, including the nutritive quality of the egg contents. *White Leghorn* hens are the chief breed for egg production in the United States and they produce *white* shells. Upon a closer look, it is significant that this *White* Leghorn breed of hen has *white* ears under their feathers.

Brown eggs (brown-colored egg shells) are popular in some regions of the United States, and with some individuals. The eggs are from slightly larger birds (requiring more feed), and they are not as prevalent as white shell eggs; therefore, for those reasons, brown eggs are usually more expensive than white. Brown eggs are produced from a *different* breed of hen than white eggs—notably hens with *reddish-brown* ears, such as *Rhode Island Red hens*, *Plymouth Rock hens*, *and New Hampshire breeds*.

Brown eggs are more difficult to classify by candling as to interior quality than are white eggs (United States Department of Agriculture (USDA)). In addition to the white and brown eggs, some egg shells are bluish or greenish. (Yes, the ears of the chicken are of that same color tinge!)

The yolk color depends on the *feed* given to the hen. As mentioned earlier, yolks may be a *deep* yellow pigment due to carotene, xanthophyll, or lycopene in the feed (not necessarily of vitamin A potential), or they may be *pale* yolks.

CULINARY ALERT! Color is not an indication of quality or nutritive value.

- Shell color—due to breed
- Yolk color—due to feed

Changes Due to Aging

Changes to the egg that occur with age are numerous. For example, contents inside the shell *shrink* and the air cell enlarges due to water loss (Jordan et al. Bulletin #612). The yolk flattens as the vitelline membrane thins, and the surrounding thick white becomes thinner, no longer holding the yolk centered in the egg. Also, the thick white thins as sulfide bonds break, and it loses CO_2 with age. Subsequently the pH rises to a more alkaline level—from 7.6 to 9.6, which allows bacterial growth. Along with these changes, another alteration with age is that the chalazae cord appears less prominent.

Abnormalities of an Egg Structure and Composition

Abnormalities in the structure and composition of eggs may be detected with or without candling (see "Candling" section). Consumers with first-hand experience may be familiar with some of these abnormalities. The USDA cites examples:

- Double-yolked egg—results when two yolks are released from the ovary about the same time or when one yolk is lost into the body cavity and then picked up when the ovary releases the next day's yolk.
- Yolkless eggs—usually formed around a bit of the tissue that is sloughed off the ovary or oviduct. This tissue stimulates the secreting glands of the oviduct and a yolkless egg results.
- Egg within an egg—one day's egg is reversed in direction by the wall of the

oviduct and is added to the next day's egg. A shell is formed around both.

- Blood spots—rupture of one or more small blood vessels in the yolk follicle at the time of ovulation, although chemically and nutritionally they are fit to eat.
- Meat spots—either blood spots that have changed in color due to chemical action, or tissue sloughed off from the reproductive organs of the hen.
- Soft-shelled eggs—generally occur when an egg is prematurely laid and insufficient time in the uterus prevents the deposit of the shell (e.g., minerals).
- Thin-shelled eggs—may be caused by mineral deficiencies, heredity, or disease.
- Glassy- and chalky-shelled eggs—caused by malfunctions of the uterus of the laying bird. Glassy eggs are less porous and will not hatch but may retain their quality.
- Off-colored yolks—due to substances in feed that cause off-color.
- Off-flavored eggs—may be due to certain feed flavors, such as fish oil or garlic. Eggs stored near some fruits and vegetables or chemicals readily absorb odors from these products.

Egg Function

The function of eggs is important to the processing facilities, retail foodservice operations, and the consumer alike, who depend on eggs for many uses in food preparation. Due to the any number of functions of an egg, a recipe formulation without eggs may not exhibit the same qualities as one that contains eggs. "Eggs supply aeration and provide structure resulting in moist, flavorful and tender baked foods. And eggs give you a clean ingredient label naturally" (American Egg Board (AEB), Park Ridge, IL).

Eggs are multifunctional products. Perhaps the contents of eggs are not ingested! Or in various ethnic holiday celebrations—the egg shell may be filled with confetti.

CULINARY ALERT! Some of the functions of eggs are listed in Table 10.3.

A high-quality egg that is fit for the consumer is one without blemishes and with a shell that is intact and clean.

Inspections and Grading for Egg Quality

Eggs are subject to inspections and are graded for quality. The USDA grades eggs on a fee-for-service basis in order to assign grades. Grading involves an evaluation of the exterior shell, its shape, texture, soundness (it should not be broken), and cleanliness, as well as the interior white and yolk, and air-cell size. Lesser grades and older eggs may be used successfully in other applications than high-grade, fresh eggs.

The 1970 Federal Egg Products Inspection Act provides the assurance that egg products are *wholesome and unadulterated* and that plants processing egg products are *continuously inspected*. Grading though is voluntary, although most eggs on the retail market are graded under federal inspections (USDA), according to established standards.

Candling

Candling is a technique that allows a view of the shell and *inside* of eggs without breaking the shell—double yolks and so forth may be seen. *Candlelight* was once used for inspecting the interior of eggs, where egg contents could be seen when held up to a candle while being rapidly rotated—thus the name *candling*. Today, commercial eggs may be scanned in mass, with bright

Table 10.3 Some of the functions of eggs in food systems

• ***Binder***
Eggs are viscous and they coagulate (to a solid or semisolid state); therefore, they bind ingredients such as those in meatloaf or croquettes, and they bind breading
• ***Clarifying agent***
Raw egg whites coagulate around foreign particles in a hot liquid. For example, when added to liquid, eggs whites seize loose coffee grounds in a coffee pot, and they clarify broth and soups, bringing the stray material to the surface for subsequent removal
• ***Emulsifier***
Egg yolks contain phospholipid emulsifiers, including lecithin. Emulsifiers allow two ordinarily immiscible liquids, such as oil and water to mix in the preparation of mayonnaise
• ***Foaming***, ***leavening agent***, ***aeration***
Egg whites increase 6–8 times in volume when beaten to a ***foam***. As the egg white foam is heated, the protein coagulates around air cells, maintaining a stable foam structure. Egg white foams leaven angel food cake and are created for meringues and desserts
• ***Gel***
A two-phase system of liquids in solids forms as eggs coagulate, forming a gel in custards
• ***Thickening agent***
Eggs coagulate and thicken mixtures such as custards and hollandaise sauce
• ***Other***: color, flavor, nutritive value, surface drying and crisping, etc. Eggs serve numerous other roles in foods
Egg yolk carotenoids add yellowish color to baked products, or yolks may be spread on dough to brown, dry, glaze, and impart a crusty sheen
Fat provides flavor, *inhibits crystal formation* in sugars, and inhibits staling
Eggs provide *nutritional value* in cooked or baked food mixtures

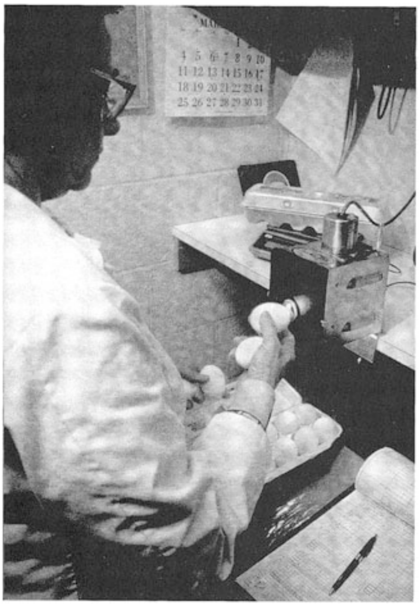


Fig. 10.2 Candling eggs by hand (*Source*: USDA)

lights under trays of eggs. The USDA bases grades on candling quality, evaluated either by hand (Fig. 10.2) or by mass scanning (Fig. 10.3).

Candling may be completed *either* at the farm or at the egg distributor before eggs are sold to the consumer. *External* observation of the shape and cleanliness of the shell may occur prior to or subsequent to candling. A candler will also form occasional comparisons of the broken-out, internal appearance evaluation with candled appearance.

CULINARY ALERT! Blood spots may be undesirable to some consumers; however, they pose no health hazard.

Letter Grades

Letter grades are issued voluntarily. Letter grades are based on candled quality and may appear as shields on the egg cartons. Grade shields on the carton indicate that the eggs were graded for quality and checked for size under the supervision of a trained packer. Packers who do *not* choose to use the federal USDA grading service are monitored by *state* agencies, and may *not* use the federal USDA grade shield.

Fig. 10.3 Candling by mass screening (*Source*: USDA)

Fig. 10.4 USDA emblem certifying quality (*Source*: USDA)

The USDA grade shields are shown in Fig. 10.4. The USDA assigns a grade of "AA" to the highest quality egg. Even this high quality may quickly diminish if eggs are exposed to improper storage conditions (USDA).

Referencing a recent *Wall Street Journal* article, the USDA shield of approval is no guarantee of safety (http://online.wsj.com/article/SB10001424052748704791004575466014072143010.html).

Occasional micrometer measurements of thick albumen egg height may also be carried out in a grading office where samples are tested (see Figs. 10.5 and 10.6).

> In the grading process, eggs are examined for both interior and exterior quality before they're sorted according to weight (size). Grade quality and weight (size) are not related to one another. Eggs of any quality grade may differ in weight (size). In descending order of quality, grades are designated AA, A and B. (American Egg Board (AEB), Park Ridge, IL)
>
> See more on egg grades

Air Cell

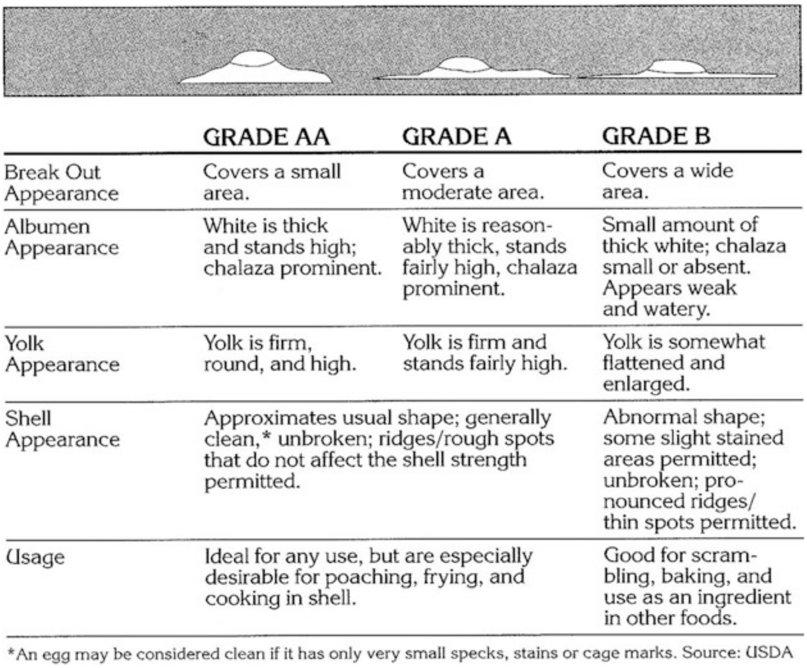
The ***air cell***, also known as the *air sac* or *air pocket*, is the empty space formed at the large end of the egg. By definition, it holds oxygen. Initially, there is either *no* air cell or a small one. Then it becomes large and apparent to the eye when the warm egg cools, the egg contents shrink, and the *inner* membrane pulls away from the *outer* membrane. The air cell increases in size with *age*, *cooling*, *and moisture loss*. It could result in microbial spoilage due to the plentiful oxygen it supplies to microorganisms.

Oftentimes a large air cell is noted in *older* eggs as they are shelled for consumption. As mentioned above, due to the fact that oxygen is available, microbial spoilage may follow development of a large air cell, as O_2 migrates to the yolk. It is recommended, therefore, that eggs should be packed with the large, blunt end of the egg *up*. If packed and stored in this manner, air movement from the cell to the yolk is minimized.

According to the American Egg Board, "Although the air cell usually forms in the large end of the egg, it occasionally moves freely toward the uppermost point of the egg as the egg is rotated. It is then called a free or floating air cell. If the main air cell ruptures, resulting in one or more small separate air bubbles floating beneath the main air cell, it is known as a bubbly air cell." (American Egg Board (AEB), Park Ridge, IL)

An acceptable air-cell size for the different grades is as follows: 1/8 in. for Grade AA, 3/16 in. for Grade A, and no limit in air-cell size for Grade B quality eggs.

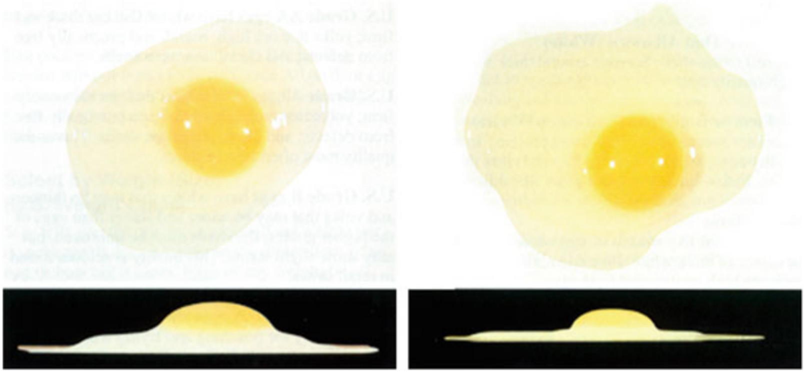
Fig. 10.5 Grades of eggs (*Source*: California Egg Commission)



	GRADE AA	GRADE A	GRADE B
Break Out Appearance	Covers a small area.	Covers a moderate area.	Covers a wide area.
Albumen Appearance	White is thick and stands high; chalaza prominent.	White is reasonably thick, stands fairly high, chalaza prominent.	Small amount of thick white; chalaza small or absent. Appears weak and watery.
Yolk Appearance	Yolk is firm, round, and high.	Yolk is firm and stands fairly high.	Yolk is somewhat flattened and enlarged.
Shell Appearance	Approximates usual shape; generally clean,* unbroken; ridges/rough spots that do not affect the shell strength permitted.		Abnormal shape; some slight stained areas permitted; unbroken; pronounced ridges/thin spots permitted.
Usage	Ideal for any use, but are especially desirable for poaching, frying, and cooking in shell.		Good for scrambling, baking, and use as an ingredient in other foods.

*An egg may be considered clean if it has only very small specks, stains or cage marks. Source: USDA

Fig. 10.6 Quality standards for grades (*Source*: USDA)



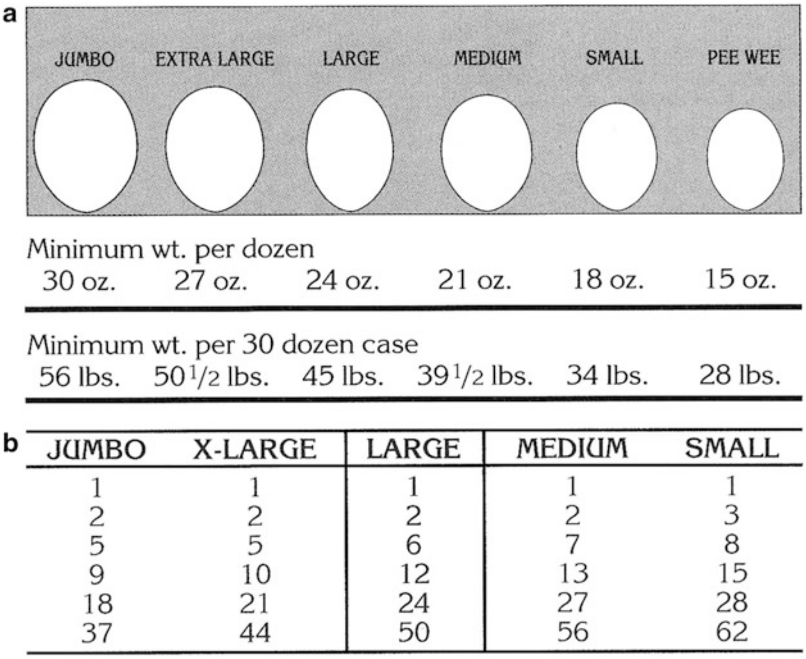
CULINARY ALERT! As a consequence of formation of large air cells, older eggs will float if placed in a bowl of water. Floating is an indication of less desirable eggs. The consumer may be familiar with the "floating" test.

Egg Size

Egg-size comparisons are shown in Fig. 10.7. The USDA does *not* include an evaluation of egg *size* as a part of egg *quality*. USDA classifications according to size and weight (minimum weight per dozen) are as follows:

• Jumbo	30 ounces (4 per cup)
• Extra large	27 ounces
• Large	24 ounces (5 per cup)
• Medium	21 ounces
• Small	18 ounces
• Pee wee	15 ounces

There is a difference of 3 ounces per dozen between each size class. Knowing the ounces in the various sizes assists with calculating pricing



Minimum wt. per dozen

30 oz.	27 oz.	24 oz.	21 oz.	18 oz.	15 oz.

Minimum wt. per 30 dozen case

56 lbs.	50 1/2 lbs.	45 lbs.	39 1/2 lbs.	34 lbs.	28 lbs.

JUMBO	X-LARGE	LARGE	MEDIUM	SMALL
1	1	1	1	1
2	2	2	2	3
5	5	6	7	8
9	10	12	13	15
18	21	24	27	28
37	44	50	56	62

Fig. 10.7 Egg sizes (*Source*: California Egg Commission)

as the best value may be computed by comparing price *per ounce*. Of course, pricing of *individual* eggs may still be costed out also. Although undesignated in many recipes for the consumer at home, *large* eggs are the standard size egg used in published recipes.

The primary factor in determining egg size is the *age* of the hen; an *older* hen produces a larger egg. Secondary factors influencing egg size are the *breed* and *weight* of the hen. The quality of the feed, as well as henhouse overcrowding and stress, all impact size, perhaps negatively.

USDA services available to volume purchases of eggs appear in Fig. 10.8.

Processing/Preservation of Eggs

Processing or preservation treatments for eggs may occur both for food safety purposes and to keep the egg fresher, longer, therefore limiting negative quality changes. Eggs are laid at a hen's body temperature and require subsequent refrigeration. It is possible to hold an egg for 6 months in cold [29–32 °F (0 °C)] storage if the shell pores are closed. Fresh eggs have thick whites and thus do not run when cracked. They contain a very pronounced chalazae cord. Over time, eggs lose moisture and CO_2.

Shell eggs or egg products may be preserved in the subsequent manners.

Mineral Oil

Mineral oil application is one means of preserving eggs. When oil is applied, it partially closes the shell pores and allows less microorganism permeability. It also allows an egg to hold more moisture within, retain its CO_2, and be protected against a pH rise in storage. Shell eggs may be sprayed or dipped in mineral oil on the same day they are laid, and washing off by consumers is unnecessary. Mineral oil dips or sprays may cause a hard cooked egg to be more difficult to peel.

Pasteurization

Pasteurization is a process required by the Food and Drug Administration (FDA) for all

Large		Small	Medium	X-Large	Jumbo
1	=	1	1	1	1
2	=	3	2	2	2
3	=	4	3	3	2
4	=	5	5	4	3

Fig. 10.8 USDA shell egg certification (*Source*: USDA)

commercial liquid, dry, or frozen egg products that are out of the shell. This treatment destroys microorganisms such as *Salmonella* bacteria that can travel from the digestive tract and droppings of birds into the egg, causing foodborne illness infection. The USDA requires a process of pasteurization that achieves a temperature of 140–143 °F (60–62 °C), held for 3-1/2 min or longer. This is less time than fluid milk and its typical 30 min pasteurization.

Pasteurization must allow maintenance of the functional properties of the egg. For example, following pasteurization, egg *whites* can still be whipped for use in a meringue although they need a longer time period to beat to a foam, and *yolks* or *whole eggs* remain functional when used as emulsifiers. Prior to pasteurization, *aluminum sulfate* may be added to egg whites in order to stabilize conalbumin protein that becomes unstable at a pH of 7.0.

Ultrapasteurization of liquid whole eggs combined with aseptic packaging creates a commercial product with numerous advantages over frozen or shell eggs. According to a market leader in refrigerated ultrapasteurized liquid whole eggs and scrambled egg mixture, the eggs have a shelf life of 10 weeks when stored between 33 and 40 °F (1–4 °C). The eggs are *Salmonella*-, *Listeria*-, and *E. coli*-negative. The eggs are not frozen, so that they are not subjected to freezer-to-refrigerator storage, which can result in a loss of functional properties.

Freezing

Freezing is a means of preservation. Since the eggs are broken open they must first be pasteurized prior to freezing. *Uncooked whites* retain their functional properties after freezing and thawing, whereas *cooked* whites exhibit ***syneresis*** (water leakage) upon thawing.

Whole eggs and *yolks* may *gel* and become gummy upon thawing, as a result of an aggregation of low-density lipoproteins in the yolk. Gumminess is controlled by sugar, corn syrup, or salt addition. Processors may add the enzyme papain in order to hydrolyze the protein. As water is bound to the enzyme, the defrosted product exhibits less gel formation.

CULINARY ALERT! A 10 % sugar solution (1 tablespoon of sugar per cup of eggs, household measure), a 5 % inclusion of corn syrup, or 3 % salt (1 tablespoon per cup of eggs) may be added to yolks before freezing as a control against aggregation. Choose the solution according to egg usage.

Dehydration

Egg dehydration is a simple process of preservation that began in the 1870s. Over the years dehydration has been much improved. It offers microbial control to egg products when water levels are reduced by techniques such as spray drying or drying on trays (producing a flaked, granular form). The dehydrated whole egg, white, yolk, or blend is then packaged in various sized packages or drums. Subsequently, it may be reconstituted and cooked, or added as an ingredient to packaged foods such as cake mixes or pasta.

Egg *whites* require the removal of glucose prior to dehydration in order to improve storage stability, because, otherwise glucose in the whites leads to unacceptable browning and flavor changes. The browning is a result of the Maillard reaction (nonenzymatic) of proteins and sugars in long or hot storage. Glucose may be removed by *lactobacillus* microbial fermentation or by enzymatic fermentation with commercial enzymes such as glucose oxidase or catalase.

Egg *yolks* undergo irreversible changes in their lipoprotein structure when dehydrated, losing some functional and desirable sensory characteristics. Dried eggs should be kept cold to meet food safety guidelines.

Storing Eggs

Storage of eggs requires cold temperatures as well as other significant conditions. For example, it is recommended that the consumer should store eggs on an *inside* shelf of the refrigerator, large end up, *not* on the door where the temperature is *warmer*. Whether it is 1 dozen eggs or flats of 30 dozen or more, eggs should be kept *in the carton* in which they were obtained, in order to prevent moisture loss and the absorption of odors and flavors from other refrigerated ingredients.

CULINARY ALERT! Hard cooked (boiled) eggs may be retained in a refrigerated unit for up to 1 week. Any break-out portions of egg may be safely stored under refrigeration in this manner: yolks in water, for 1–2 days, whites in a covered container for up to 4 days.

The USDA-graded eggs are washed, sanitized, oiled, graded, and packaged soon after they are laid, and it is usually a matter of days between the egg leaving the hen house and reaching the supermarket. Cold temperatures, high humidity, and proper handling are required in storage, and, when kept cold, eggs may be safely stored for 45 days past the pack date.

According to the American Egg Board, "Egg cartons from USDA-inspected plants must display a Julian date—the date the eggs were packed. Although not required, they may also carry an expiration date beyond which the eggs should not be sold. In USDA-inspected plants, this date cannot exceed 30 days after the pack date. It may be less through choice of the packer or quantity purchaser such as your local supermarket chain. Plants not under USDA inspection are governed by laws of their states." (American Egg Board (AEB), Park Ridge, IL)

Many eggs reach stores only a few days after the hen lays them. Egg cartons with the USDA grade shield on them must display the "pack date" (the day that the eggs were washed, graded, and placed in the carton). The number is a three-digit code that represents the consecutive day of the year (the "Julian Date") starting with January 1 as 001 and ending with December 31 as 365. When a "sell-by" date appears on a carton bearing the USDA grade shield, the code date may not exceed 45 days from the date of pack.—USDA

Denaturation and Coagulation: Definitions and Controls

Denaturation may be mild or extensive. It occurs when a protein molecule (helical shape) unfolds, changing its nature (thus the word denaturing). This is an *irreversible* change in the specific folding and shape that a protein assumes in space.

Denaturation of the protein in an egg may occur due to *heat*, *mechanical action* such as beating or whipping, or an *acidic pH*. Regardless of the cause, the helical chains with intramolecular bonds uncoil and align in a parallel fashion, forming intermolecular bonds, and the protein chains shrink.

In the *raw* state, eggs appear *translucent* because light is refracted and passed between individual proteins. As the egg denatures, the egg changes in appearance from translucent to *opaque* or *white*. Once *cooked*, light is no longer able to pass between the newly formed protein mass.

Coagulation represents the *further* process that occurs when denatured protein molecules form a solid mass. The liquid/fluid egg (which is a sol) is converted into a solid or semisolid state (which is a gel). Water escapes from the structure as unfolded helixes attach to each other.

This coagulation occurs over a wide temperature range and is influenced by factors previously mentioned such as heat, beating, pH, and also use of sugar and salt. Coagulation results in the precipitation of the protein and is usually a *desirable* characteristic.

Curdling may occur next. Beyond denaturation and coagulation, *undesirable curdling* of egg mixtures results in an egg mixture shrinking or becoming tough. Some factors involved in denaturation, subsequent coagulation, and possible curdling are as follows:

Heat

- Heat should be slow and mild. The egg *white* denatures, coagulates, and becomes solid at temperatures of 144–149 °F (62–65 °C). Egg *yolks* begin to coagulate at 149 °F (65 °C) and become solid at 158 °F (70 °C). *Whole eggs* coagulate at an intermediate temperature. In the preparation of an egg mixture such as an egg custard, the rate of heating and intensity of heat must be controlled. These heating characteristics are discussed below.

- **Rate and coagulation**:
  A *slow* rate of heating safely coagulates the egg mixture at a lower temperature than a *rapid* rate of heating. A slow rate provides the "margin of error" or *extra time* (for possibly interrupting cooking) between the coagulation temperature and undesirable, fast approaching curdling. A *rapid* rate of heating may quickly exceed the desired temperature and result in undesirable curdling.
- **Intensity and coagulation**:
  A *mild* heating intensity denatures and coagulates with desirable molecular associations. As opposed to this, *intense* heating applies too much heat, too quickly, and causes undesirable curdling with negative changes such as water loss and shrinkage (Chap. 8).
- **Water bath and coagulation**:
  Using a water bath controls *both* the rate and intensity of coagulation.
  It is therefore an advisable baking strategy for baking egg dishes, commercially and at home. The reason it works is that the egg product is placed in an external water medium that cannot exceed the boiling temperature of water.

Additional factors influencing the denaturation and coagulation of eggs include the following:

- **Surface changes**. Beating, and so forth, denatures the helical protein structure. This is readily seen in the white color (explained above) and increased volume of egg white foams used for the preparation of meringues.
- **Acid pH**. An acid pH coagulates egg protein. For example, adding acid to the water used for poaching eggs coagulates the egg white so that it remains small and compact. As well, acid in the cooking water offers control, by immediately coagulating undesirable strands of leakage escaping from cracks in eggs that are hard cooked.

CULINARY ALERT! Acidic cooking water may cause difficulty in peeling an older, more alkaline egg. Thus older eggs, which have become alkaline with age, may be cooked in salted water.

Effect of Added Ingredients on Denaturation and Coagulation

In addition to the aforementioned surface changes and acidic pH of the water, extra ingredients in an egg mixture may affect both the denaturation and coagulation processes.

Sugar. The addition of sugar exerts a protective effect on the egg by controlling the rate of denaturation and ultimate formation of intermolecular bonds. This is seen in the preparation of meringues. The foam in the meringue will not be as large if sugar is added early, *prior* to denaturation. For larger foams, sugar should be added late, *after* the egg white has denatured.

Sugar also raises the temperature required for coagulation. A custard prepared *with* sugar has a *higher* coagulation temperature than a similar egg–milk mixture *without* sugar but produces no change in the finished gel (Chap. 14).

Salt. When salt is added, it promotes denaturation, coagulation, and gelation. Salt may be a constituent of food, such as the *milk salts* in milk, or it may be *added* to a product formulation. Milk salts contribute to custard gelation, whereas the addition of water to eggs does *not* promote gelation.

Acid level. As the pH *decreases* and becomes more acidic, coagulation of the egg white occurs more readily. An older, more alkaline egg will result in *less* coagulation than a fresh, neutral pH egg. Vinegar may be added to the water of poached and hard cooked egg to aid in denaturation and coagulation *and* to prevent spreading of egg strands. Coagulation depends on which egg protein is involved, and its isoelectric point (pI)—the point at which a protein is least soluble and usually precipitates.

Other ingredients. Ingredients such as fat vary and therefore all specifics cannot be addressed (Fig. 10.9). Egg is often diluted by the addition of other substances in a food system. For example, the coagulation temperature is *elevated* if an egg mixture is made dilute by water or milk. If a mixture is diluted, a less firm finished product results.

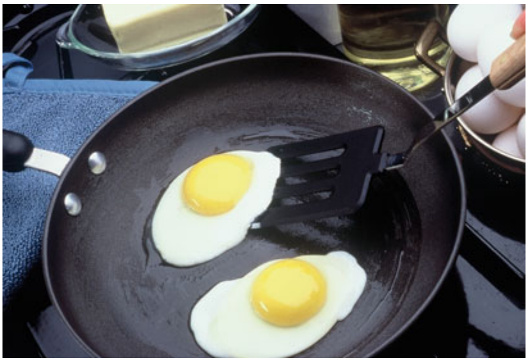


Fig. 10.9 Pan-fried egg

Cooking/Baking Changes

Cooking typically produce noticeable egg changes, hopefully while keeping a tender, high-quality product. With the expected/continued rise in gluten-free baked products, eggs offer nutritional and functional property benefits for those foods. “Egg products contribute humectancy, that helps optimize moisture for better density and rise, and prevents dry, crumbly characteristics often associated with gluten-free formulations” (Foster 2013).

Several cooking methods include the following:

Pan Frying:

- Method: Eggs placed in a preheated pan coagulate the egg proteins.
- Heated pan: A preheated pan allows coagulation before the egg has an opportunity to spread. However, an overheated pan may overcoagulate the egg and produce a tough product.
- Use of fat: Pan Frying in a measurable amount of fat and basting the top of the egg with fat produce a tender egg, but may not be desirable in terms of the calorie and fat contribution that is offered.

CULINARY ALERT! Eggs may be pan-“fried” in liquids other than fat or oil, and the pan lid may remain in use to create steam that cooks the egg’s upper surface.

Hard Cooked Eggs:

"Hard boiled" is another, yet less appropriate, term for these "hard cooked" eggs. (*boiling* the eggs is not desirable)

- Method: It is recommended that eggs be placed one layer deep in a covered saucepan of boiling water, and then simmered, not boiled, for 15–18 min for a hard cooked egg, or just 2–5 min for a soft "boiled" egg. More than one layer deep, or placing eggs in cold water at the start of cooking, may retard the "doneness" of hard cooked eggs.

  Alternative method: Place the eggs one layer deep in an uncovered saucepan of cold water. Heat water to boiling. Then, remove the pot from the stove burner and cover. Allow standing time of 9 min for medium eggs and 12 min for large eggs.
- Peeling: Eggs should be cooled *rapidly* to facilitate easier peeling. Fresh eggs may be difficult to peel, in part because an alkaline pH has not yet been achieved.
- Cracking: In order to prevent cracking from an expansion of air in the air cell, and the buildup of internal pressure, it may be recommended that the egg be punctured at the large end. However, this seemingly logical step has *not* been shown to prevent cracking of the shell. For prevention, the egg may be warmed slightly prior to cooking.
- Color: Green discoloration of hard cooked eggs occurs with long and high heat exposure. The green color is due to the formation of *ferrous sulfide* from *sulfur* in the egg white protein combining with *iron* from the yolk. "Greenish yolks can best be avoided by using the proper cooking time and temperature and by rapidly cooling the cooked eggs." (American Egg Board (AEB), Park Ridge, IL)

CULINARY ALERT! Hard *cooked* is the term of choice when referring to "hard *boiled* eggs." Eggs are more tender when they reach a simmering, not boiling temperature.

Custard

- Method: Custards (served plain or incorporated into cream desserts, flan, or quiche) are cooked with a *slow rate* of heating. This provides a margin of error that protects against a rapid temperature elevation from the point of coagulation to undesirable curdling where the protein structure shrinks and releases water. Custards cooked with the addition of a starch white sauce are able to withstand higher heat because starch exerts a protective effect on the denatured proteins.
- *Stirred* custard: Custards may be stirred or baked. Soft, *stirred* custard will cling to a stirring spoon, as it thickens. It remains pourable and does not form a gel. If overheated, or heated too quickly, the mixture curdles and separates into curds and whey. Therefore, the use of a double boiler is recommended in order to control temperature and the rate of cooking. As mentioned, starch may be added to the formulation in order to prevent curdling.
- *Baked* custard (see Fig. 10.10) reaches a *higher* temperature than stirred custard and gels. Baking in a *water bath* is recommended in order to control the rate and intensity of heat and prevent the mixture from burning. With the addition of starch in a recipe, this is not required. Cooking/holding for an extended period of time, even in a water bath, could cause syneresis.
- Texture: The texture of an egg custard is dependent on a number of factors, including the extent of egg coagulation and added ingredients. A well-coagulated custard is fine textured; a curdled custard is extremely porous, tough, and watery.

Fig. 10.10 Custard baked in water bath (*Source*: American Egg Board)

CULINARY ALERT! Milk salts and added sugar raise the coagulation temperature; custards prepared with starch (such as arrowroot, cornstarch, flour, and tapioca) control curdling.

CULINARY ALERT! Cooking with a double boiler or water bath in the oven often brings success to egg custards.

Scrambled eggs
- Method: Cook with short cooking, at medium high.
- Dilution: This may result in less solid coagulation.
- Discoloration: Negative coloring may appear in eggs as ferrous sulfide forms. Avoid direct heat when holding eggs. Water may be placed between the pan of eggs and the source of heat.

Egg White Foams and Meringues

Egg white foam is created as the liquid egg whites are *beaten or whipped* to incorporate air. The egg white volume expands with beating as the protein denatures and coagulates around the many newly formed air cells.

Beaten whites are used in numerous food applications, as meringues, or incorporated into a recipe to lighten the structure. The volume and stability of egg white foams is dependent on conditions such as the humidity in the air, temperature of the egg, and other added substances, as shown in Table 10.4.

CULINARY ALERT! Care should be taken to gently *fold*, not *stir*, the beaten egg white foam into the other recipe ingredients. After all, it was work to create the foam, and the air cells should not be roughly treated!

A variety of food products are created using egg white foams, including cakes, dessert shells, sweet or savory soufflés, and pies. A sweet egg white foam is known as a meringue and may be either soft or hard, the latter prepared with more sugar. Examples of sweet meringue confections include pies, cookies, and candies.

The preponderance of meringues require that egg whites be beaten to either the soft or stiff peak stage, and then immediately be added to the recipe. Processors use egg white foams to create special appearance and volume for their products.

CULINARY ALERT! Use *super-fine* sugar in order to create glossy meringues. Ordinary *granulated* sugar may be successfully utilized if it is processed in the food processor for 1 min, prior to use.

Possible unsuccessful egg white foams or meringues may result if the foam is *not immediately* incorporated into a formulation or if eggs are *overbeaten*. A brief explanation: when not incorporated immediately, the recipe may lose some of its characteristic elasticity, and, upon standing, become stiff and brittle. If overbeaten, the foam is not able to expand with heat since the eggs have now become inelastic.

A further error results from using *cold* temperature eggs. These cold eggs have a high surface tension and do not beat to as high a volume as *room temperature* eggs. It is recommended to allow eggs to reach room temperature for better whipping, although this practice carries with it the increased risk of salmonella growth.

CULINARY ALERT! Rather than setting eggs out to slowly warm to room temperature, and encouraging bacterial growth, egg whites may

Table 10.4 Some factors affecting the volume and stability of egg white foams

Temperature—The temperature of eggs influences beating ability. At room temperature, eggs have less surface tension and are more easily beaten than if they were cold. Yet, at warm temperatures, Salmonella may grow and cause illness in susceptible individuals
pH—Acid should be added in the whipping process *after* eggs reach the foamy stage and have large air cells. If acid substances such as cream of tartar are added to raw egg whites at the *beginning* of the beating process, there is less volume although greater stability due to intramolecular bond coagulation
Salt—Salt adds flavor. Its presence delays foam formation, and, if added early in the beating process, produces a drier foam with less volume and stability. Salt should be added to egg white foams at the foamy stage or later if flavor is needed
Sugar—The protective effect of sugar on eggs has been discussed
Early addition
The early addition of sugar causes less intermolecular bonding of the egg proteins than would occur in the absence of sugar. Therefore, the addition of sugar results in an egg foam that is stable, but has less volume. A fine-textured, more stable foam develops if finely ground sugar is added *early* in the beating process
Late addition
Sugar (2–4 tablespoons per egg white, respectively, for soft or hard meringues) should be added to foams gradually, at the soft peak or stiff peak stage of development, *after* large air cells have formed and denaturation has begun. On a damp day, the preparation area may contain a lot of humidity that is absorbed by the sugar, and this results in a softer meringue (hydroscopicity Chap. 14)
Fat—Traces of fat may remain in the equipment used for beating egg white foams, or it may originate from the egg yolk, or be introduced by another added ingredient in the product formulation. If fat enters the egg white, there will be substantially less foaming, and less volume. Fat interferes with the foaming that would occur if protein aligned itself around the air cell and coagulated
Liquid—The addition of liquid dilutes the egg white. A benefit is that added liquid, such as water, will increase volume and tenderness of foams, yet it results in a less stable, softer foam and an increased likelihood of syneresis. Dried egg white that has been reconstituted with a liquid requires longer beating time than fresh egg whites, due to some protein breakdown in the drying process
Starch—Starch assists in controlling coagulation in proteins; starch is of benefit to soft meringues. A starch should first be cooked and then incorporated into the meringue

be slightly warmed by placing the appropriate number of separated egg whites in a bowl over warm water. This allows the egg whites to warm up prior to successful whipping.

Leavening is diminished if *older* eggs are used for the creation of foams. While older eggs whip up more easily than fresh eggs, protein does not coagulate well around the air cells and there is a higher percentage of thin whites that create large, unstable foams.

Egg *yolks* contain fat that physically interferes with the alignment of protein around air cells. Therefore, the yolks should be *completely* separated from the whites, not allowing *stray* yolk to enter the white in separation. Separation works easier when eggs are cold. Although egg yolks cannot form foams, they may be beaten to become thicker. They may be used in other cooking applications.

It may be common practice to separate the yolk and white by passing the egg contents between the two broken halves of the shell. Repeatedly passing the egg contents from one shell to the other releases the white and retains the yolk. A warning though: The American Egg Board offers information about separating eggs. “Bacteria are so very tiny that, even after washing and sanitizing, it’s possible that some bacteria may remain in the shell’s pores. The shell might also become contaminated from other sources. When you break or separate eggs, it’s best to avoid mixing the yolks and whites with the shells. Rather than broken shell halves or your hands, use an inexpensive egg separator or a funnel when you separate eggs to help prevent

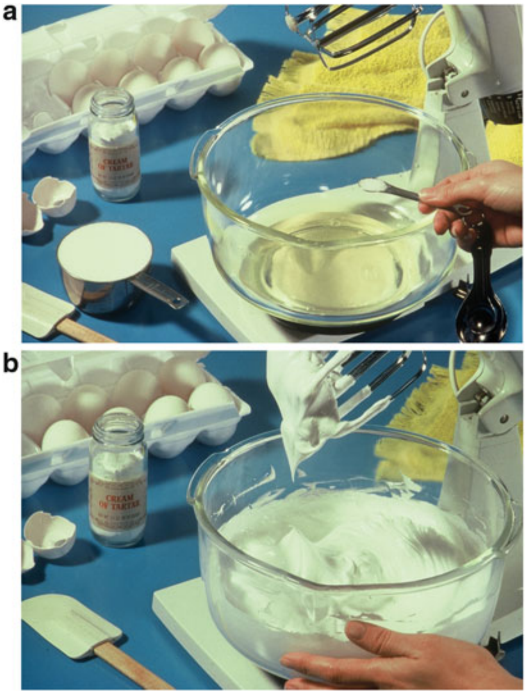


Fig. 10.11 Unbeaten (*top*) and beaten egg whites (*bottom*) after addition of acid and sugar (*Source*: American Egg Board)

introducing bacteria. Also use a clean utensil to remove any bits of eggshell that fall into an egg mixture and avoid using eggshells to measure other foods." (American Egg Board (AEB), Park Ridge, IL)

Commercial egg *substitutes* may be successfully used in the preparation of foams since they consist primarily of whites and contain no fat. They are similar to shell egg whites, aside from imparting the yellowish color.

A further point to address in egg meringues is the use of copper bowls for creating meringues. Copper bowl usage for beating egg whites has been a recommendation over the years. However, it turns out that conalbumin protein from the egg white combines with traces of copper from the bowl, producing *copperconalbumin*. There is no noticeable effect in the *unbaked* foam; however, due to toxicity issues, the use of copper bowls is no longer recommended.

Hard meringues may be a key ingredient of some cookies or candy. Soft meringues are used most notably on pie (Fig. 10.11). The special problems that may arise with soft meringues are shrinking, weeping, and beading. A hot oven and cold pie filling may be responsible for these problems in the same meringue.

Weeping is the release of water from *under*coagulated (perhaps underbeaten or undercooked) egg white foam. A release of water at the interface of meringue and filling may form a water layer causing the meringue to slide off. This occurs if the meringue is placed on a *cold* filling.

Consequently, to prevent weeping, prepare the meringue first and then the already-prepared meringue may be placed on a *hot* filling and *immediately* baked. Both the filling and the oven should be hot. Another method used for control is the addition of ½ to 1 teaspoon of cornstarch to the sugar prior to beating it into the eggs.

Beading is apparent in *over*coagulated (overcooked) meringues. Beading appears as drops of amber-colored syrup on top of meringue. It may be the result of (1) adding too much sugar, or the insufficient incorporation of the sugar into the beaten egg whites. It may also be the result of (2) baking too long, at a low temperature. For control, a high temperature for a short time is needed.

CULINARY ALERT! Placing one layer of meringue at a time, after the previous layer adheres to the filling, is helpful in maintaining a meringue. As well, a fine layer of breadcrumbs may be sprinkled on the hot filling prior to topping with the meringue.

A brief look at the stages of denaturation when egg whites are beaten to foam appears in Table 10.5

CULINARY ALERT! Slicing a gummy, sticky, beading meringue surface is better with the use of a sharp serrated knife dipped in cold water prior to each slice.

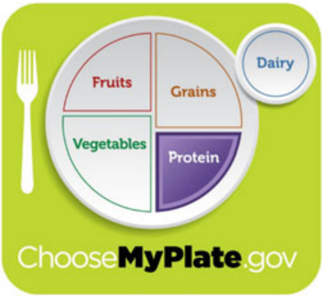
Egg Products and Egg Substitutes

Egg products and egg substitutes on the market include pasteurized, processed, refrigerated liquid, frozen, and dried eggs that are available for commercial and retail users.

If in *liquid* form, eggs may be ultrapasteurized or aseptically packaged to extend shelf life. ***Egg substitutes*** have *no* yolks and may contain 80 % egg white. Generally, the "yolk" is made of corn oil, nonfat milk solids (NFMS), calcium caseinate, soy protein isolate, soybean oil, and other substances, including vitamins and minerals. The egg substitute also contains no cholesterol, less fat, and more unsaturated fat than whole egg. Many US egg patents have been issued relating to low-fat and low or decholesterized egg products.

CULINARY ALERT! Egg substitutes although yellowish in color may be beaten for use in egg white foams.

Nutritive Value of Eggs



Grains Group	Vegetable Group	Fruit Group	Dairy Group	Protein Foods Group
Make at least half your grains whole.	Vary your veggies.	Focus on fruits.	Get your calcium-rich foods.	Go lean with protein.

The nutritive value of eggs includes vitamins A, D, E, the water-soluble Bs, and minerals such as iron, phosphorus, and zinc as well as iodine, potassium, and sulfur. Eggs are low in calories—75 cal per large egg—and are used to fortify other foods that may originally be low in protein.

Eggs are a complete protein, with a ***biological value*** of 100, which indicates that all of the protein is retained by the body. All other protein sources are evaluated against this standard. That is not to say that eggs are "the perfect food." Persons who follow an ovo-vegetarian diet include eggs in their diet and assist in meeting essential protein requirements.

Egg whites are given the highest ***protein-digestibility-corrected amino acid score*** (***PDCAAS***) of 1.0, which corrects the amino acid composition with its digestibility.

For FDA labeling purposes, the PDCAAS method of determining protein quality is used. The % Daily Value for protein that appears on labels reflects both the quantity (in grams) and quality of protein (Table 10.6).

New, Digestible Indispensable Amino Acid Score (DIAAS) as a replacement for PDCAAS has been proposed. See this press release:

FAO Proposes New Protein Quality Measurement

The Food and Agriculture Organization of United Nations (FAO) has released a report recommending a new, advanced method for assessing the quality of dietary proteins. The report, "Dietary protein quality evaluation in human nutrition," recommends that the Digestible Indispensable Amino Acid Score (DIAAS) replace the Protein Digestibility Corrected Amino Acid Score

Table 10.5 Beaten egg white foam

Stage	Description
Unbeaten raw egg white	• Small volume of thick and thin whites
	• No initial additives
Foamy	• Unstable, large air-cell volume, transparent
	• Bubbles coalesce if beating is halted
	• Acid coagulates protein around air cell
	• Add cream of tartar (acid) now
Soft rounded peaks	• Air cells subdivide in size and are whiter
	• Volume is increased
	• Add sugar now
	• May be used for food applications
	• Used for soft meringue
Stiff pointed peaks	• Many small air cells, volume is increased
	• Egg protein coagulates around fine air cells
	• Ready for most food applications
	• Used for hard meringue
Dry peak foam	• Brittle, inelastic; less volume as air cells break
	• Denatured, water escapes, ***flocculated***
	• Not as effective as a leavening agent
	• Overcoagulated, curdled appearance

Table 10.6 PDCAAS of selected foods

Egg white	1	Chick peas	0.66
Casein (milk)	1	Pinto beans	0.63
Soybean isolate	0.99	Rolled oats	0.57
Beef	0.92	Lentils	0.52
Kidney beans	0.68	Whole wheat	0.40

(PDCAAS) as the preferred method of measuring protein quality.

The report recommends that more data be developed to support full implementation, but in the interim, protein quality should be calculated using DIAAS values derived from fecal crude protein digestibility data. Under the current PDCAAS method, values are "truncated" to a maximum score of 1.00, even if scores derived are higher. . .

http://www.fao.org/ag/humannutrition/35978-02317b979a686a57aa4593304ffc17f06.pdf

Egg yolks contain cholesterol, and consequently are restricted by some individuals with known heart disease. Over the past years, the American Heart Association (AHA) has changed its recommendations to where the current recommendation for intake is now consuming seven eggs per week. Dietary sources of cholesterol do not equate to personal levels of blood cholesterol (American Egg Board (AEB), Park Ridge, IL)

How much the cholesterol in a person's diet increases blood cholesterol varies from person to person. See the 2012 published research with references http://www.incredibleegg.org/health-and-nutrition

Statement by the Egg Nutrition Center and American Egg Board on Recently Published Research on Egg and Cholesterol Consumption

Park Ridge, Ill. (August 14, 2012)—Eggs have been shown to have a wide range of health benefits, providing 13 essential vitamins and minerals, high-quality protein and International contamination of eggs with SE is very low, even from a known positive flock (American Egg Board (AEB), Park Ridge, IL). Yet, the safety of eggs must be ensured. For example, only clean, uncracked eggs should be purchased from a reputable supplier. Exterior surface bacteria can enter shells of dirty eggs, or even clean ones, especially through cracks causing the egg to be unsafe.

A Harvard study with more than one hundred thousand subjects found no significant difference in cardiovascular disease risk between those consuming less than one egg per week and those consuming one egg per day. The researchers concluded that consumption of up to one egg per day is unlikely to have substantial overall impact on the risk of heart disease or stroke among healthy men and women. Another study published in Risk Analysis estimates that eating one egg per day is responsible for less than one percent of the risk of coronary heart disease in healthy adults. Alternatively, lifestyle factors including poor diet, smoking, obesity, and physical inactivity contribute to 30–40 % of heart disease risk, depending on gender. . .

Additionally, research has shown that saturated fat may be more likely to raise a person's serum cholesterol than dietary cholesterol. . .

Also see about reevaluating eggs' cholesterol risk:

http://www.sciencenews.org/view/generic/id/7301/description/Reevaluating_Eggs_Cholesterol_Risk

The American Heart Association cautions, for people with existing "coronary heart disease, diabetes, high-LDL cholesterol or other cardiovascular disease, your daily cholesterol limit is less than 200 mg."

The Egg Nutrition Center site is for anyone who wants to learn about eggs and good nutrition. The truth is, an egg a day is OK! http://www.enc-online.org/.

"Egg Nutrition Center (ENC) monitors scientific findings and regulatory developments, and serves as a resource for health practitioners in need of current nutrition information to share with their patients. Key vehicles for disseminating information are the Nutrition Close-Up newsletter, various educational brochures and tool kits, published scientific articles, and symposia presented at health professional conferences and the eggnutritioncenter.org website."

See also:

http://www.incredibleegg.org/health-and-nutrition/cracking-the-cholesterol-myth

Cracking the Cholesterol Myth

More than 40 Years of Research Supports the Role of Eggs in a Healthy Diet

Many Americans have shied away from eggs—despite their taste, value, convenience, and nutrition—for fear of dietary cholesterol. However, more than 40 years of research have shown that healthy adults can eat eggs without significantly impacting their risk of heart disease.

And now, according to new **United States Department of Agriculture** (USDA) nutrition data, eggs are lower in cholesterol than previously recorded. The USDA recently reviewed the nutrient composition of standard large eggs and results show the average amount of cholesterol in one large egg is 185 mg, a 14 % decrease. The analysis also revealed that large eggs now contain 41 IU of vitamin D, an increase of 64 %.

For more information, contact the Egg Nutrition News Bureau at 312-233-1211 or info@eggnutrition.org.

"Research shows diets with increased protein are beneficial for weight loss, specifically to reduce body fat, protect lean tissue, increase satiety and stabilize glycemic indices like blood sugar and triglycerides." Suggested is "a high protein-rich breakfast reduces hunger, boosts satiety and reduces brain responses involved with food cravings to a greater degree than a typical breakfast that's lower in protein." (Lockwood et al. 2006)

Below is a Nutrition Facts Label Printed Directly on an Egg still subject to on-going testing:

Nutrition Facts
Serving Size 1 egg (50g)
Amount Per Serving
Calories 70 Calories from Fat 40
% Daily Value
Total Fat 4.5g 7%
Sat. Fat 1.5g 8%
Trans Fat 0g
Cholesterol 215mg 71%
Sodium 65mg 3%
Total Carb. Less than 1g 0%
Protein 6g 10%
Vitamin A 6% Vitamin C 0
Calcium 2% Iron 4

See: TipSheet no. 6 (in Meats)

American Egg Board

Realities/misconceptions

Issue	Misconception	Fact
Salmonella	Eggs pose a serious risk of foodborne illness due to salmonella contamination	Eggs used in processed foods are from further processed eggs which are pasteurized and free from *Salmonella*. Keep in mind that proper food handling is still important with further processed eggs
Cholesterol	For many years, consumers and the media have viewed eggs as a high cholesterol food associated with high blood cholesterol levels	Studies have shown that saturated fat, not dietary cholesterol from eggs, is the real culprit. Most healthy people can include eggs in their diet
Egg substitutes and replacers	Food processors sometimes believe that ingredients provide better functions than real eggs in formulations	Eggs provide superior polyfunctional properties. Food processors find that replacers do not function as well as real eggs in various food applications. Often a replacer provides one function only. For example, the substitute may act as a foaming agent but exhibits poor coagulation properties

"Egg protein contributes essential functional and nutritional properties" and "is well suited for a variety of gluten-free applications." (Foster 2013)

Safety of Eggs

"SAFE HANDLING INSTRUCTIONS" on egg labels assists in preventing illness from bacteria. This product warning provides instructions that include keep eggs refrigerated, cook eggs until yolks are firm, and cook foods containing eggs thoroughly.

The contents of freshly laid eggs are generally sterile, although ***Salmonella enteritidis*** (***SE***) has been found inside some eggs. Eggs are *usually* protected from bacteria by the shell and the two shell membranes; however, the surface of shell eggs may contain a high level of bacteria. These bacteria may enter the shell through the pores, especially when it is soiled and washed. If bacteria travel to the internal portion of the egg, it is typically the *egg yolk membrane* (i.e., the vitellin membrane), *not* the yolk itself nor the egg white that harbors the bacteria.

According to the American Egg Board, "… protective barriers include the shell and yolk membranes and layers of the white which fight bacteria in several ways. The structure of the shell membranes helps prevent the passage of bacteria. The shell membranes also contain *lysozyme*, a substance that helps prevent bacterial infection. The yolk membrane separates the nutrient-rich yolk from the white." (American Egg Board (AEB), Park Ridge, IL)

The Egg Safety Action Plan, a joint effort by the FDA and USDA, was announced in the late 1999. Its intent was to reduce the incidence of SE, and it contains two important requirements:

1. The refrigeration requirement in this Plan is that eggs delivered to a retail establishment (restaurants, hospitals, schools, nursing homes, grocery stores, delis, and vending operations) be quickly stored at an ambient temperature of 45 °F (7 °C) or less upon receipt
2. There is a required statement on shell egg cartons that reads as follows:

   According to the FDA raw eggs should not be used, especially by population groups such as the young, elderly, or immune-compromised.

Food Safety and Pregnancy

Safe Eats—Eating Out & Bringing In

Food Safety for Moms-to-Be

Welcome to Safe Eats, your food-by-food guide to selecting, preparing, and handling foods safely throughout your pregnancy and beyond!

Meat, Poultry & Seafood|Dairy & Eggs|Fruits, Veggies & Juices|Ready-to-Eat Foods|Eating Out & Bringing In

For a printable chart of cooking temperatures, see the Apply the Heat (PDF | 20.3KB) chart

The Food and Drug Administration (FDA) cautions, "During pregnancy, your immune system is weakened, which makes it harder for your body to fight off harmful foodborne microorganisms that cause foodborne illness." How can you safeguard the health of yourself and your baby? See some tips from the FDA.

Raw eggs or undercooked eggs are the most common source of Salmonella illness (salmonellosis). The U.S. National Pasteurized Eggs, Inc. (NPE), producer of Safest Choice™ pasteurized eggs, has received the 2011 NSF Food Safety Leadership Award in Breakthrough Technologies for its in-shell egg pasteurization process. "In-shell pasteurized eggs may be used safely without cooking."—USDA

Some USDA and FDA rulings follow:

As Recommended by the USDA: Dates on Egg Cartons

Use of either a "Sell-by" or "Expiration" (EXP) date is not federally required, but may be State required, as defined by the egg laws in the State where the eggs are marketed. Some State egg laws do not allow the use of a "sell-by" date. Many eggs reach stores only a few days after the hen lays them. Egg cartons with the USDA grade shield on them must display the "pack date" (the day that the eggs were washed, graded, and placed in the carton). The number is a three-digit code that represents the consecutive day of the year starting with January 1 as 001 and ending with December 31 as 365. When a "sell-by" date appears on a carton bearing the USDA grade shield, the code date may not exceed 45 days from the date of pack. (The day that the eggs were washed, graded, and placed in the carton.)

Always purchase eggs before the "Sell-by" or "EXP" date on the carton. After the eggs reach home, refrigerate the eggs in their original carton and place them in the coldest part of the refrigerator, not in the door. For best quality, use eggs within 3–5 weeks of the date you purchase them. The "sell-by" date will usually expire during that length of time, but the eggs are perfectly safe to use.

fsis.usda.gov

The FDA prohibits the use of raw or lightly cooked eggs in food production or manufacturing facilities. Eggs must reach an internal temperature of 145 °F (63 °C) or higher to be considered safe for consumption (check local jurisdiction). Egg products must be pasteurized. A previous FDA Commissioner added ". . . no sunny side up, no over easy." (Dr. Jane E. Henney, FDA Commissioner)

International contamination of eggs with SE is very low, even from a known positive flock (California Egg Commission, Upland, CA). Yet, the safety of eggs must be ensured. For example, only clean, uncracked eggs should be purchased from a reputable supplier. Exterior surface bacteria can enter shells of dirty eggs, or even clean ones, especially through cracks causing the egg to be unsafe.

Check your steps at FoodSafety.gov. Also see the chapter on Food Safety.

Some foods are more frequently associated with food poisoning or foodborne illness. With these foods, it is especially important to:

- CLEAN: Wash hands and food preparation surfaces often. And wash fresh fruits and vegetables carefully.
- SEPARATE: Don't cross-contaminate! When handling raw meat, poultry, seafood, and eggs, keep these foods and their juices away from ready-to-eat foods.
- COOK: Cook to proper temperature. See the Minimum Cooking Temperatures chart for details on cooking meats, poultry, eggs, leftovers, and casseroles.
- CHILL: At room temperature, bacteria in food can double every 20 min.

Also, The President's Council on Food Safety has encouraged developments in science and technology by companies and universities to reduce the incidence of SE. For example, methods are being investigated/employed to bring an egg temperature down from 109 °F (43 °C) (the internal temperature of hens) to a cold temperature of 45 °F (7 °C) to control SE. One such method utilizes cryogenic carbon dioxide; another uses a clean warm-water bath to kill bacteria without cooking (Praxair Inc. 2000; Mermelstein 2000).

Furthermore since washing is a routine step in commercial egg processing, rewashing eggs prior to use is not necessary or recommended. When eggs are washed in warm water and then refrigerated, pressure changes in a cooling egg draw harmful exterior microbes in through the pores. Eggs should be stored cold at temperatures of approximately 40 °F (4.4 °C).

CULINARY ALERT! The common restaurant practice of "pooling" (commingling) eggs is not recommended. Pooled eggs are many eggs cracked together and stored ahead, ready to use such as for an omelet. Contamination likelihood is increased.

Prior to incorporation into recipes, either egg yolks or the egg white to be used for meringue may be heated over direct heat or water bath to raise temperature while controlling SE. If the egg is refrigerated, bacterial growth is extremely slow, and disease is not likely to result. Egg products are pasteurized and free of *Salmonella*.

Safety: Easter Egg Dyeing and Hunts—USDA

Easter eggs are a fun tradition for many families but they can be a health hazard if not handled properly.

Dyeing eggs: After hard cooking eggs, dye them in food-safe coloring and return them to the refrigerator within 2 h.

Blowing out eggshells: Only use uncracked, refrigerated eggs. Wash the egg in hot water and then rinse in a solution of 1 tablespoon of unscented, liquid chlorine bleach in 1 gallon of water. This will destroy bacteria that may be present on the surface of the shell.

Hunting for eggs: If you are preparing an Easter egg hunt with hard-boiled eggs, use extra caution when hiding the eggs to prevent the shell from cracking. If the shell cracks, bacteria and germs can contaminate the egg. Eggs should not be out of the refrigerator for more than 2 h. Once eggs have been found (within the 2 h time), re-refrigerate immediately and consume within 7 days. Do not eat if shell is cracked or if eggs were unrefrigerated for more than 2 h (or 1 h if over 90 °F).

USDA

Hard cooked eggs reach a final cooking temperature that is sufficient to kill the natural bacteria of an egg, yet *recontamination* may occur. For example, recontamination may be due to the practice of "hiding Easter eggs" wherein the oil coating of the egg may be lost, and the pores of the egg may open. Subsequently, the egg may be contaminated with substances such as lawn chemicals, fertilizers, or droppings from household pets, birds, reptiles, and rodents (American Egg Board (AEB), Park Ridge, IL). Refrigerate after cooking—perhaps quick chill in an ice bath.

Accordingly, for consumers who follow the traditional practices of decorating and hiding Easter eggs, the USDA caution remains: Keep perishables at room temperature for no longer than 2 h. Decorated eggs are festive and may be very inexpensive and are thus included in many celebrations, but the recommendation is that separate eggs be used for eating and decorating or "hiding."

Egg White Resistance to Bacterial Growth

Egg whites have natural protection against microorganisms by several natural *chemical components*; however, they cannot be considered 100 % safe once the shell has been broken or cracked. These components include *avidin*, *lysozyme*, and *conalbumin*. *Avidin* in the raw egg white binds the vitamin biotin required for some microorganism growth. *Lysozyme* hydrolyzes cell walls of some bacteria and thus demonstrates antibacterial action, especially at lower pH levels. *Conalbumin* binds with the iron of the yolk preventing growth of the microorganisms that require iron for growth.

Pasteurized raw eggs in uncooked foods such as mayonnaise do not support the growth of bacteria as do unpasteurized shell eggs. Thus, only pasteurized egg products may be used in manufacturing or retail operations, where a food containing eggs is not subject to adequate heat treatment. Uncooked meringues prepared by shell egg whites that are not pasteurized are considered a "low-risk" food though, because they contain a large amount of sugar that ties up the water needed for bacterial growth. The water activity needs of the bacteria are not met, and the bacteria do not grow.

CULINARY ALERT! Some risk of bacterial presence exists in eggs and it is recommended that all raw egg parts, including egg whites, be cooked prior to use.

"In addition to containing antibacterial compounds such as lysozyme, layers of the white discourage bacterial growth because they are alkaline, bind nutrients bacteria need and/or don't provide nutrients in a form that bacteria can use. The thick white discourages the movement of bacteria. The last layer of white is composed of thick ropey strands which have little of the water that bacteria need but a high concentration of the white's protective materials. This layer holds the yolk centered in the egg where it receives the maximum protection from all the other layers." (American Egg Board (AEB), Park Ridge, IL)

USDA Sampling

The USDA-administered Egg Products Inspection Act of 1970 requires routine sampling and analysis, and routine inspection for wholesome, unadulterated eggs and egg products. Plants are inspected regardless of whether the shipment is intrastate, interstate, or out of the country. State standards, regulated by the state's Department of Agriculture, must be equivalent to federal standards.

Conclusion

Whole eggs, and their component parts, are important for their array of functional properties such as binding, emulsification, foaming, gelling, and thickening. These properties change with cooking as the egg protein denatures. The processes of grading and evaluation of quality, although not mandatory, are officially carried out by the USDA and their state counterparts.

Eggs are candled in order to evaluate and assign grades. In candling, the yolk, white, and air-cell size as well as the integrity of the shell are viewed prior to sale. Egg size is not a part of egg quality evaluation. The color of a shell is dependent on the breed of hen, and the yolk color is dependent on the feed.

Processing and preservation of eggs occurs with the use of mineral oil and the techniques of pasteurization, freezing, and dehydration, after which proper storage is important in maintaining safety and other aspects of food quality. The addition of other ingredients to an egg, such as salt and acid, promotes denaturation. Sugar exerts a protective effect, controlling the denaturation and coagulation processes. Some factors affecting the volume and stability of egg white foams include temperature, pH, salt, sugar, fat, and addition of liquid. The recommendation is that eggs not be old or cold.

Various forms of eggs, including pasteurized shelled eggs, are available, and egg substitutes may be purchased in the marketplace. Eggs have a biological value of 100, and are given the highest PDCAAS. The Food and Agriculture Organization of United Nations (FAO) has released a report that recommends that the Digestible Indispensable Amino Acid Score (DIAAS) replace the (PDCAAS) as the preferred method of measuring protein quality. Vigilance is necessary in the handling and use of eggs, a potentially hazardous food.

"Most healthy people can include eggs in their diet."(American Egg Board (AEB), Park Ridge, IL). "Egg ingredients are available in liquid, frozen or dried forms as whole eggs yolks and whites, or tailored to meet processing specifications." (American Egg Board 2013)

Notes

CULINARY ALERT!

Glossary

Air cell or air pocket A space between shell membranes where air is found within the shell, typically at the large end of an egg.

Biological value Eggs contain a score of 100 based on their efficiency in supporting the body's needs; reflects the amount of nitrogen retained in the body, due to the completeness of the protein. (An incomplete protein is deaminated and nitrogen is not retained.)

Beading Amber-colored syrup beads on top of baked meringue as a result of overcoagulation.

Binder Holds the ingredients of a mixture or its breading together.

Candling Viewing the inside and shell of an egg by holding it up to a bright light.

Clarify To remove foreign particles from a hot liquid.

Coagulation Extensive denaturation of protein molecules yielding a solid mass or gel.

Curdling The protein precipitates, shrinks, releases water, and becomes tough.

Denaturation Changes in the conformation of a protein caused by changes in temperature, an acidic pH, or by surface changes such as mechanical beating.

Digestible Indispensable Amino Acid Score (DIAAS) A measure of protein quality. The preferred method of measuring protein quality recommended to replace the PDCAAS.

Egg substitute Liquid or frozen egg white product with a "yolk" typically consisting of corn oil, NFMS, calcium caseinate, soy protein isolate, soybean oil, and other substances.

Emulsifier Material that allows two ordinarily immiscible substances to mix.

Flocculated Separation of overbeaten egg white foam into small masses.

Foam Increased volume of beaten egg white that holds shape as protein coagulates around air cells.

Gel A two-phase system where egg coagulates with liquid in a solid.

Pasteurization Heating for a specific time at a temperature that eliminates pathogens.

Protein-digestibility-corrected amino acid score (PDCAAS) A measure of protein quality that compares the amino acid balance with requirements of preschoolers and corrects for digestibility. Used by the FDA for labeling and by the WHO.

Digestible Indispensable Amino Acid Score (DIAAS) It has been proposed as a replacement for PDCAAS. More data needs to be developed to support full implementation.

***Salmonella enteritidis* (SE)** Pathogenic, infection-causing bacteria especially prevalent in poultry and eggs.

Syneresis "Weeping" or water leakage from coagulated egg.

Thickening agent Increases viscosity.

Ultrapasteurization High temperature, short time heat to kill pathogenic microorganisms.

Weeping Syneresis or release of water from undercoagulated or underbeaten egg whites.

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Model FDA Food Code

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Milk and Milk Products

11

Introduction

Milk is the first food of young mammals produced by the mammary glands of female mammals. It is a mixture of fat and high-quality protein in water and contains some carbohydrate (lactose), vitamins, and minerals. Milk and milk products may be obtained from different species, such as goats and sheep, although the focus of this chapter is on *cow's* milk and milk products.

While fluid milk contains a very large percentage of water, it may be concentrated to form evaporated milk and cheeses. Throughout the world, it is used in a variety of ways, such as a beverage, cheese, yogurt, or in soups and sauces.

By law, milk and milk products must contain a designated percent of ***total milk solids*** (all of the components of milk except water), and also, the ***milk solids***, ***not fat*** (***MSNF***) (all of the components of milk solids not including fat). The butterfat component of milk is the most expensive component of milk and its level determines if milk is offered for retail sale as whole milk or at some lesser percentage of fat, such as 2 % milk, 1 %, 1/2 %, or fat-free.

Milk may be cultured, dried, fortified, homogenized, or pasteurized and used to create products with different taste, texture, nutritive value, and shelf life. It may be processed into products such as buttermilk, cheese, cream, ice milk, ice cream, sour cream, and yogurt with different levels of fat content. Dried milk is added to a multitude of foods. It may be added to foods to increase the protein or calcium value.

The top eight milk-producing states produce 196.2 billions of pounds as follows:

California	21.1 %
Wisconsin	13.3
Idaho	6.8
New York	6.5
Pennsylvania	5.4
Texas	4.9
Minnesota	4.5
Michigan	4.3
All others	33.1 %
Source: USDA (2011)	

Total Milk Production has gone from 165.3 billions of pounds in 2001 to the 196.2 billion pounds in 2011 shown above.

High temperatures may curdle milk; therefore, care must be taken in the preparation of foods with milk. Milk requires safe handling and cold storage.

Milk is not well tolerated by a large portion of the population. The milk sugar, lactose, is not digested by persons lacking the enzyme lactase.

Definition of Milk

> Milk means the lacteal secretion, practically free from colostrum, obtained by the complete milking of one or more healthy cows, which may be

V.A. Vaclavik and E.W. Christian, *Essentials of Food Science, 4th Edition*, Food Science Text Series, DOI 10.1007/978-1-4614-9138-5_11,

> clarified and may be adjusted by separating part of the fat there from; concentrated milk, reconstituted milk, and dry whole milk. Water, in a sufficient quantity to reconstitute concentrated and dry forms may be added. (FDA)

Further useful Food and Drug Administration (FDA) definitions, such as that for cheese, appear later in this chapter.

Composition of Milk

Milk varies in physical and chemical composition depending on such factors as age and breed of the cow, activity level, stage of lactation, use of medication, and interval between milking. It consists mainly of water and contains some serum solids or milk solids, nonfat (MSNF) such as lactose, caseins, whey proteins, and minerals. Milk also naturally contains fat.

Water

Water is the largest component of milk and is present at a level of approximately 87–88 %. If that water is removed, the shelf life of milk products is greatly extended.

Carbohydrate

Carbohydrate is water-soluble and present in the aqueous phase of milk, at levels of slightly less than 5 %. The disaccharide *lactose* is the main carbohydrate. It exhibits low solubility and may precipitate out of solution as a grainy textured substance. It is converted to lactic acid (1) upon souring due to bacterial fermentation and (2) in the process of aging cheese. Therefore, aged cheese may be digestible by lactose-intolerant individuals even in the absence of the enzyme lactase. (The lactose content of milk and some milk products appears in Table 11.2. See section “Lactose Intolerance.”)

Fat

Fat has a low density and may *easily* be centrifuged or *skimmed off* of the milk yielding low-fat or *skim milk*. The fat, or butterfat, exists at levels of approximately 3.5 % in whole milk, at lesser levels in reduced-fat or nonfat milks, and at *significantly* higher percentages in cream. Fat is the expensive component of milk and the basis on which dairy farmers are paid for milk. When fat and its carotenoids are removed, milk is bluish in color.

Fat globules are less dense than the water in the aqueous phase of milk and, therefore, rise to the top of the container in the ***creaming*** process. When emulsified during *homogenization*, there is an increase in the number of fat cells and greater viscosity because the fat is distributed throughout the fluid, and creaming does *not* occur. Membranes of lipids and protein, including lecithin, from each fat globule remain in the milk as it is processed.

Fat content in milk varies greatly in calories. The completeness of milking determines richness of the fat content. Milk either carries or may be fortified to contain the fat-soluble vitamins, and it contains the pigments carotene and xanthophyll. Fat contains the sterol cholesterol and phospholipids, although it is primarily triglyceride (95 %) with saturated, polyunsaturated, and monounsaturated fatty acid components. These have varying melting points and susceptibility to oxidation. The fatty acid chains contain many short-chain fatty acids such as the saturated butyric acid (4 °C) and caproic, caprylic, and capric acids.

A number of the more than 400 individual fatty acids have been identified in milk fat. It is approximately 15–20 *fatty acids* that make up 90 % of the milk fat. *Phospholipids* (such as phosphatidylcholine and sphingomyelin) in cell membranes compose approximately 1 % of the fat in milk.

Protein

Protein represents 3–4 % of the composition of milk and components may be fractioned out of milk by *ultracentrifugation*. ***Casein** is the primary protein of milk*, comprising approximately 80 % of the milk protein. The caseins are actually a group of similar proteins, which can be separated from the other milk proteins by acidification to a pH of 4.6 (the isoelectric point). At this pH, the caseins aggregate, since they are hydrophobic, are poorly hydrated, and carry no net charge. The other milk proteins, being more hydrophilic, remain dispersed in the aqueous phase.

There are three main casein fractions, known as alpha$_s$-, beta-, and kappa-casein (α_s-, β-, and κ-casein). Alpha$_s$-casein actually comprises two fractions: α_{s1}-casein and α_{s2}-casein. However, these two fractions are difficult to separate from each other. The four fractions α_s-, β-, κ-, and α_{s2}-casein occur in the weight ratio 3:3:1:0.8. All four fractions are phosphoproteins containing phosphate groups esterified to the amino acid serine. The α_s- and β-casein fractions contain several phosphate groups and as a result are "calcium-sensitive" and may be coagulated by addition of calcium. Kappa-casein contains only one phosphate group and is not calcium-sensitive. The α_s- and β-casein fractions are very hydrophobic. However, κ-casein is a glycoprotein containing an acidic (charged) carbohydrate section, and so it is much more hydrophilic.

In milk, the casein fractions associate with each other and with colloidal calcium phosphate to form stable spherical structures known as ***casein micelles***. The more hydrophobic α_s- and β-casein fractions exist mainly in the interior of the micelles, whereas the more hydrophilic κ-casein exists mainly on the micelle surface. It is the κ-casein that gives the micelles their stability in milk under normal handling conditions.

This is due to the negative charge and hydration of the κ-casein, coupled with the fact that the charged hydrophilic carbohydrate section of the molecule tends to protrude from the micelle surface in hairlike structures, which confer steric (or spatial) stability on the micelles. Also, since κ-casein is not sensitive to calcium, it protects the other caseins from the ionic calcium in milk, thereby increasing the stability of the micelles.

There have been several different views of the structure of the casein micelles, and their structure is still debated. Two major structural models have been postulated. The submicelle model was developed first and was prominent for many years. That model consists of aggregates of casein submicelles linked by calcium phosphate. It is suggested that there are κ-casein-rich and κ-casein-poor micelles, with the former being present at the surface of the micelles. However, there is not sufficient evidence for the existence of discrete submicellar particles.

The most current view of casein micelle structure is a nanocluster model, which is an open structure involving calcium phosphate nanoclusters surrounded by casein phosphopeptides. The caseins bind to more calcium phosphate or to other caseins, thus forming the casein micelles. This could be considered an inversion of the submicelle model. The calcium phosphate nanoclusters vary in density and provide for a porous structure that is able to hold a large amount of water. In both models, the κ-casein is mainly present at the surface and has a stabilizing effect on the micelles.

There are many reviews of casein micelle structure for those who would like to dig deeper on this subject. A good starting place would be the recent review by Dalgleish and Corredig (2012).

The casein micelles are *coagulated by addition of acid* at a pH of 4.6–5.2. As the micelles approach their isoelectric point, the charge and extent of hydration is reduced, and the κ-casein hairlike structures flatten, reducing steric hindrance. Hence, the micelles are no longer stable, and so they aggregate. This is the basis for the formation of cottage cheese, which is an acid cheese containing casein curds.

Acid also causes some calcium to be removed from the micelles, and so cottage cheese is relatively low in calcium compared with some other dairy products. The casein micelles may also be *coagulated by addition of the enzyme* ***rennin***, which may be added to milk to prepare rennet custard or cheese. Rennin cleaves a specific bond in κ-casein and causes the charged, hydrophilic hairlike structures to be removed from the micelles.

Accordingly, the micelle surface is uncharged, hydrophobic, and unstable, and so the micelles aggregate to form curds. The curds may be separated from the whey and processed to form cheese (see section on "Cheese"). Coagulation by rennin does not cause calcium to be removed from the micelles.

Casein micelles are relatively heat stable and are not denatured by heat (at neutral pH) unless temperatures are very high and heating is prolonged. This is not a problem under most cooking conditions. However, it is a potential problem in heated concentrated milk products such as evaporated milk. The problem is avoided by addition of carrageenan to protect the protein.

Caseins contain both hydrophobic and hydrophilic sections; in addition, they contain a high proportion of the amino acid proline, and so they are flexible proteins containing little regular, ordered secondary structure (see Chap. 8). As a result, they readily adsorb at an oil–water interface, forming a stable film that prevents coalescence of emulsion droplets (see Chap. 13), and so they make excellent emulsifiers.

A *second protein fraction* of milk is the ***whey*** or serum. It makes up approximately 20 % of milk protein and includes the *lactalbumins* and *lactoglobulins*. Whey proteins are more hydrated than casein and are denatured and precipitated by heat, rather than by acid. (More information is contained in this chapter in the section entitled "Whey.")

Additional significant protein components of milk include enzymes such as lipase, protease, and *alkaline phosphatase*, which hydrolyze triglycerides, proteins, and phosphate esters, respectively. The average measures of protein quality, including biological value, digestibility, net protein utilization, protein efficiency, and chemical score, for milk and milk products appear in Table 11.1.

Vitamins and Minerals

Vitamins in milk are both the water-soluble and fat-soluble varieties. The nonfat portion of milk is especially plentiful in the B vitamin B_2—riboflavin, a greenish fluorescent colored vitamin. It acts as a photosynthesizer and is readily destroyed upon exposure to sunlight.

Additional *water-soluble B vitamins* in milk beside riboflavin include thiamin (vitamin B_1), niacin (vitamin B_3), pantothenic acid (vitamin B_5), vitamin B_6 (pyridoxine), vitamin B_{12} (cobalamin), vitamin C, and folate.

The *fat-soluble vitamins A, D, E, and K* are dependent upon the fat content of the milk. Vitamin A is *naturally* in the fat component of *whole* milk, and more may be added prior to sale. If the milk is reduced fat (2 % fat), or low-fat (1 % fat), or even skim milk (fat skimmed off), fortification with vitamin A must occur in order to be made nutritionally equivalent to whole milk.

Whole milk is generally (98 %) *fortified* with *vitamin D* because it is naturally present only in *small* amounts. Vitamin D is present in milk to *some* extent due to the synthesis of vitamin D by the cow as it is exposed to sunlight and because vitamin D may be present in animal feed. *Low-fat* and *nonfat* milk, containing reduced levels or no fat, may be fortified with *both* of these fat-soluble A and D vitamins. Fortification with vitamin D is voluntary. Vitamins E and K are minor constituents of milk.

Minerals such as calcium and phosphorus are present at levels of approximately 1 % of milk, with a third of calcium in solution, and two-thirds of it colloidally dispersed. Calcium is combined with the protein casein as calcium caseinate, with phosphorus as calcium phosphate and as calcium citrate. Other minerals present in milk are chloride, magnesium, potassium, sodium, and sulfur.

Classification of Milk

Whole milk may be classified as a solution, dispersion, or emulsion as follows:

Table 11.1 Average measures of protein quality for milk and milk products

	BV	Digestibility	NPU	PER[a]	Chemical score
Milk	84.5	96.9	81.6	3.09	60
Casein	79.7	96.3	72.1	2.86	58
Lactalbumin	82	97	79.5[b]	3.43	[c]
Nonfat dry milk	–	–	–	3.11	–

Source: Adapted from the National Dairy Council

Note: *Biological* value (BV) is the proportion of absorbed protein that is retained. *Digestibility* (*D*) is the proportion of food protein that is absorbed. *Net protein utilization* (NPU) is the proportion of food protein intake that is retained (calculated as BV × *D*). *Protein efficiency ratio* (PER) is the gain in body weight divided by weight of protein consumed. *Chemical score* is the content of the most limiting amino acid expressed as a percentage of the content of the same amino acid in egg protein

[a] Often, PER values are adjusted relative to casein which may be given a value of 2.5

[b] Calculated

[c] Denotes no value compiled in Food and Agriculture Organization of the United Nations (FAO) report

Table 11.2 Composition of milks from different species (100-g portions)

Nutrient	Cow	Human	Buffalo	Goat	Sheep
Water (g)	87.99	87.50	83.39	87.03	80.70
Calories	61	70	97	69	108
Protein ($N \times 6.38$) (g)	3.29	1.03	3.75	3.56	5.98
Fat (g)	3.34	4.38	6.89	4.14	7.00
Carbohydrate (g)	4.66	6.89	5.18	4.45	5.36
Fiber (g)	0	0	0	0	0
Cholesterol (mg)	14	14	19	11	–
Minerals					
Calcium (mg)	119	32	169	134	193
Iron (mg)	0.05	0.03	0.12	0.05	0.10
Magnesium (mg)	13	3	31	14	18
Phosphorus (mg)	93	14	117	111	158
Potassium (mg)	152	51	178	204	136
Sodium (mg)	49	17	52	50	44
Zinc (mg)	0.38	0.17	0.22	0.30	–
Vitamins					
Ascorbic acid (mg)	0.94	5.00	2.25	1.29	4.16
Thiamin (mg)	0.038	0.014	0.052	0.048	0.065
Riboflavin (mg)	0.162	0.036	0.135	0.138	0.355
Niacin (mg)	0.084	0.177	0.091	0.277	0.417
Pantothenic acid (mg)	0.314	0.223	0.192	0.310	0.407
B_6 (mg)	0.042	0.011	0.023	0.046	–
Folate (μg)	5	5	6	1	–
B_{12} (μg)	0.357	0.045	0.363	0.065	0.711
Vitamin A (RE)	31	64	53	56	42
Vitamin A (IU)	126	241	178	185	147

Source: National Dairy Council

- *Solution*—contains the sugar lactose, the water-soluble vitamins thiamin and riboflavin, and many mineral salts such calcium phosphate, citrates, and the minerals chloride, magnesium, potassium, and sodium.
- Colloidal *dispersion* (sol)—casein and whey proteins, calcium phosphate, magnesium phosphate, and citrates.
- *Emulsion*—fat globules suspended in the aqueous phase (serum) of milk. The fat globules are surrounded by a complex membrane, the milk fat globule membrane, which contains mainly protein and phospholipids (and a few carbohydrate side chains at the outer surface). This membrane prevents coalescence of the fat droplets.

Grading of Milk

Grades are based on bacterial counts. Milk is a *potentially hazardous food* that must be kept *out* of the temperature danger zone. With its high water content and plentiful protein, vitamins, and minerals, milk is an ideal medium for supporting bacterial growth. Production, processing, and distribution of milk must ensure that products are kept *free* from pathogenic bacteria and *low* in nonpathogens. *Healthy cows* and *sanitary* conditions of handling lead to *low* bacterial counts. *Proper handling* also contributes to satisfactory shelf life, as well as appearance, flavor, and nutritive value.

The *temperature* of raw milk should reach 40 °F (4 °C) or less within 2 h of being milked from the cow. It should be kept well chilled, as it is highly perishable and susceptible to bacterial growth. The shelf life for properly refrigerated milk is 14 days or up to 45 days for *ultra-pasteurized* milk products including cream and lactose-reduced milk (see section "Pasteurization").

Numerous factors may lead to the spread of diseases by milk or milk products. A contaminated cow, *cross-contamination* at the farm or from workers hands, and unsanitary equipment or utensils may all become problematic. Traditionally, the diseases of *diphtheria*, *salmonellosis*, *typhoid fever*, *tuberculosis*, and *undulant fever* were spread by consumption of unsafe milk. Today, the incidence of these diseases is *rarely* attributed to milk transmission, as milk is pasteurized to destroy pathogens. The control of insects and rodents, as well as separation of animal waste products from the milking area, is also necessary for safe milk production.

The *US* Department of Agriculture (USDA) and *state* Departments of Agriculture regulate milk and milk products in interstate and intrastate commerce. Grades are based on bacterial counts. Grade "A" milk is available to the consumer for sale as fluid milk, although grades "B" and "C," with higher bacterial counts, are also safe and wholesome. The grades of US Extra and US Standard are given to dried milk. USDA official grades are given to all inspected milk on a voluntary fee-for-service basis.

Enzymes such as lipase, oxidation, and light may induce deterioration of the fat.

Flavor of Milk

The flavor of milk is mild and slightly sweet. The characteristic mouthfeel is due to the presence of emulsified fat, colloidally dispersed proteins, the carbohydrate lactose, and milk salts. Fresh milk contains acetone, acetaldehyde, methyl ketones, and short-chain fatty acids that provide aroma.

Less desirable, "barny" or rancid flavors, or other "off-flavors," may be due to the following:

- Slightly "cooked" *flavor* from excessive pasteurization temperatures.
- *Animal feed*, including ragweed and other weeds, or wild onion from the field.
- *Lipase activity* causes rancidity of the fat, unless destroyed by the heat of pasteurization. (Or, the short-chain butyric acid may produce an off-odor or

off-flavor due to bacteria, rather than lipase in the emulsified water of milk.)
- *Oxidation* of fat or phospholipids in the fat globule membrane, especially in emulsified, homogenized milk. Adequate pasteurization temperatures are necessary to destroy the enzyme which oxidizes fat.
- *Light-induced* flavor changes in the proteins and riboflavin because riboflavin acts as a photosynthesizer.
- *Stage of lactation* of the cow.

Flavor treatment to standardize the odor and flavor typically follows *pasteurization*. In this treatment process, milk is instantly heated to 195 °F (91 °C) with live steam (injected directly into the product) and subsequently subjected to a vacuum that removes volatile off-flavors and evaporates excess water produced from the steam.

Milk Processing

Pasteurization

"Pasteurized, when used to describe a dairy ingredient means that every particle of such ingredient shall have been heated in properly operated equipment to one of the temperatures (specified in the table) and held continuously at or above that temperature for the specified time (or other time/temperature relationship which has been demonstrated to be equivalent thereto in microbial destruction)" (FDA). Fluid milk is *not routinely sterilized* (see below); *rather*, *it is pasteurized*. This assures destruction of the pathogenic bacteria, yeasts, and molds, as well as 95–99 % of nonpathogenic bacteria. ***Pasteurization*** minimizes the likelihood of disease and extends the storage life of milk.

Pasteurization temperatures do *not* change milk components to any great extent (see section "Nutritive Value"). Vitamin destruction and protein denaturation are minimal, and the result is that milk is made safe for consumption. Several acceptable methods of pasteurization including thermal processing according to the International Dairy Food Association (IDFA) are shown in the following chart:

- 145 °F (63 °C) for 30 or more minutes—the batch or holding method is Vat Pasteurization and is considered low-temperature longer time (LTLT) pasteurization.
- 161 °F (72 °C) for 15 s—the flash method for this temperature is the high-temperature short-time (HTST) method of pasteurization, the most common method.
- 191 °F (88 °C) for 1 s. Higher heat shorter time (HHST) at this temp and above.
- 194 °F (90 °C) for 0.5 s. HHST.
- 201 °F (94 °C) for 0.1 s. HHST.
- 204 °F (96 °C) for 0.05 s. HHST.
- 212 °F (100 °C) for 0.01 s. HHST.

IDFA

"Another method, aseptic processing, which is also known as ultra high temperature (UHT), involves heating the milk using commercially sterile equipment and filling it under aseptic conditions into hermetically sealed packaging. The product is termed "shelf stable" and does not need refrigeration until opened. All aseptic operations are required to file their processes with the FDA's "Process Authority." There is no set time or temperature for aseptic processing; the Process Authority establishes and validates the proper time and temperature based on the equipment used and the products being processed."

"If the fat content of the milk product is 10 % or more, or if it contains added sweeteners, or if it is concentrated (condensed), the specified temperature shall be increased by 3 °C (5 °F). Provided that, eggnog shall be heated to at least the following temperature and time specifications:

Temperature Time Pasteurization Type
69 °C (155 °F) 30 min—vat pasteurization
80 °C (175 °F) 25 s—HTST pasteurization
83 °C (180 °F) 15 s—HTST"
(IDFA, http://www.idfa.org/files/249_Pasteurization Definition and Methods.pdf)

Pasteurization is required of all grade A fluid milk or milk products subject to interstate commerce for retail sale. Traditionally, prevention of tuberculosis (TB) was the primary concern in pasteurization; thus, temperatures of 143 °F (62 °C) were used to destroy *Mycobacterium tuberculosis*, the bacteria causing TB in humans. Actually, *Coxiella burnetii* that causes Q fever requires an even *higher* temperature for destruction; thus, the required 145 °F (63 °C) was set for pasteurization. The high pasteurization temperature, followed by rapid cooling, controls nonpathogenic growth.

A large US foodborne illness outbreak in recent years, where many thousands of people became ill, was attributed to raw milk that inadvertently entered the wrong pipeline (not effectively prevented from entering) before packaging and subsequently contaminated the already pasteurized milk.

Many foods use enzyme tests in determining adequate pasteurization. *Adequate* pasteurization is demonstrated by the absence of the enzyme *alkaline phosphatase*. The phosphatases are highly effective in an alkaline environment. The term may be used synonymously as basic phosphatase. This enzyme is *naturally* present in milk and is *destroyed* (thus no longer present) at temperatures similar to those required for adequate pasteurization. A simple test determines its presence in milk. For example, *inadequate* pasteurization of raw milk reveals the presence of a *high* alkaline phosphatase activity. Inversely, *adequate* pasteurization shows its absence.

"Except for Michigan, not a single state law expressly prohibits the sale of raw milk for animal consumption. The variables are the states' willingness to grant licenses to producers of raw milk for animal feed and how strictly state agencies would monitor licensees to make sure that raw milk sales did only go for animal consumption" (http://www.realmilk.com).

Sterilization (ultra-pasteurization [UP])—pasteurization occurs at *higher* temperatures with a different time:

- 280–302 °F (138–150 °C) for 2–6 s

"Ultrapasteurized when used to describe a dairy ingredient means that such ingredient shall have been thermally processed at or above 280 °F for at least 2 s" (FDA). This UP process still requires that the milk be refrigerated afterward.

The use of *sterilization temperatures* in combination with the use of *presterilized containers*, under *sterile conditions*, creates ultrahigh-temperature (UHT) processing. It *does not* allow spoilage or pathogenic bacteria to enter the milk. If *packaging too* is sterilized, the package is referred to as being "*aseptically* packaged." Thus, milk treated in this manner may be safely stored up to 3 months or longer. An example of this is milk in packaging similar to "juice boxes."

The typical HTST pasteurization of fluid milk does not significantly affect the vitamin content. However, the high heat treatment of ultrahigh-temperature (UHT) pasteurization does cause losses of some water-soluble vitamins.

Regarding minerals, calcium phosphate will travel both in and out of the casein micelle with changes in temperature. Yet this process is reversible at *moderate* temperatures, although at very high temperatures the calcium phosphate may precipitate out of solution and subsequently cause irreversible changes in the casein micelle structure.

Exposure to light will cause a decrease in the levels of riboflavin and vitamin A in milk. Therefore, milk is stored in opaque plastic or paperboard containers that provide barriers to light to maximize vitamin retention. ***See*** http://www.milkfacts.info/Milk%20Composition/VitaminsMinerals.htm.

Homogenization

The primary *function* of ***homogenization*** is to *prevent creaming*, or the rising of fat to the top of the container of milk (whole or reduced-fat milks). The *result* is that milk maintains a more uniform composition with improved body and texture, a whiter appearance, richer flavor, and more digestible curd.

Homogenization *mechanically* increases the number and *reduces* the size of the fat globules. The size is reduced from 18 m to less than 2 m, or 1/10 of their original size. The process of homogenization permanently *emulsifies* the fine fat globules by a method that pumps milk under high pressure [2,000–2,500 lb/in.^{2} (psi)] through small mesh orifices of a homogenizer.

Homogenization offers a *permanent* emulsification because as the surfaces of many new fat globules are formed, each fat globule becomes coated with a part of the lipoprotein membrane and additional proteins from casein and whey. Thus, these proteins adsorb onto the freshly created oil surface *preventing* globules from reuniting or coalescing, and the fat remains homogeneously distributed throughout milk.

Milk may be homogenized *prior to* or *subsequent to* pasteurization. The homogenization process is completed at a *fast* rate to ensure the control of bacteria and loss of quality.

Various characteristics of homogenized milk include the following:

- *No creaming* or separation of cream to the top of the container.
- *Whiter* milk due to finer dispersions of fat. There is an increase in the absorption and reflection of light due to the smaller fat particles.
- *More viscous* and creamy milk due to a greater number of fat particles.
- *More bland* due to smaller fat particles.
- *Decreased fat stability* as fat globule membranes are broken.
- *Less stable to light* and may exhibit light-induced favor deterioration by sunlight or fluorescent light. Thus, paperboard cartons and clouded plastic bottles are used for milk.

Fortification

Fortification is defined as the addition of nutrients at levels beyond/different from the original food. The addition of fat-soluble vitamins A and D to *whole milk* is optional fortification. Low-fat milk, nonfat milk, and low-fat chocolate milk *must* be ***fortified*** (usually before pasteurization) to carry 2,000 International Units (IU) or 140 retinol equivalents (RE) *vitamin A* per quart. It is *required* for milk subjected to *interstate* commerce. *Vitamin D* addition to reach levels of 400 IU per quart is *optional*; however, it is routinely practiced. Evaporated milks must be fortified.

CULINARY ALERT! Vitamin A and D are fat-soluble vitamins, thus are not naturally in milk without fat. Low-/nonfat milk is fortified to contain these vitamins.

In order to add to the viscosity and appearance, as well as the nutritive value of low-fat milk, *nonfat milk solids* (*NFMS*) may be *added* to milk. This addition allows milk to reach a 10 % NFMS (versus 8.25 % usually present), and it will state “protein fortified” or “fortified with protein” on the label.

Bleaching

Bleaching carotenoid or chlorophyll pigments in milk may be desirable. The FDA allows benzoyl peroxide (BP) or a blend of it with potassium alum, calcium sulfate, or magnesium carbonate to be used as a bleaching agent in milk. The weight of BP must not exceed 0.002 % of the weight of the milk, and the potassium alum, calcium sulfate, and magnesium carbonate, individually or combined, must not be more than six times the weight of the BP. Vitamin A or its precursors *may be destroyed* in the bleaching process; therefore, sufficient vitamin A is added into the milk or in the case of cheesemaking to the curd.

The use of whey proteins in food and beverage applications is chiefly derived from annatto-colored cheddar cheese. Since not all of the annatto is removed from the whey, bleaching occurs.

Types of Milk

Fluid Milk

Fluid milk may come from goats (Mediterranean countries), sheep (southern Europe), reindeer (northern Europe), and other animal sources throughout the world. It is *Holstein* cows that typically produce the greatest quantity of milk and are, therefore, the *primary milk cow* in the United States. The Guernsey and Jersey breeds produce milk with the highest percentage of fat—approximately 5 % fat.

Milk appears *white* due to the reflection of light from colloidally dispersed casein protein and calcium phosphate particles in the milk dispersion; however, an *off-white* color may be due to carotenoid pigment in the animal feed. A *bluish* color may be observed in milk skimmed of fat and thus devoid of carotenoid pigments.

Both the fat content and percent of MSNF of fluid milk are subject to FDA regulations and new technological developments. The butterfat and caloric content of milk are as follows:

Type of milk	Fat percent	Calories
Whole	3.25	150 calories/ 8 ounce
Reduced fat	2	120 calories/ 8 ounce
Low fat or light	0.5, 1.0	100 calories/ 8 ounce (1 %)
Nonfat, fat-free/“skim” (fat skimmed off)	<0.5	90 calories/ 8 ounce

Flavored milk contains fat, protein, vitamin, and mineral contents similar to the type of milk to which the flavoring was added—whole, reduced fat, and so forth. It will vary in caloric and carbohydrate values according to added ingredients.

CULINARY ALERT! Substitutes for 1 cup whole milk:

- 1/2 cup evaporated milk + ½ cup water—reconstituted
- 1/3 cup NFMS in measuring cup + water to reach 1 cup mark of cup—reconstituted
- 1 cup buttermilk + ½ tsp. baking soda

Evaporated and Concentrated Milks

Evaporated and *condensed*, or *sweetened condensed*, coupled with packaging in cans, extends the shelf life of the milk. *Cans* of evaporated milk may be adequately stored for extended time periods, although due to the Maillard reaction (more later), undesirable tan or brownish color or flavor changes may occur after 1 year’s time. Rehydration may then be made difficult.

CULINARY ALERT! Discoloration is not indicative of possible foodborne illness. Once the can has been opened, it should be refrigerated and can be held for up to 1 week.

Evaporated milk is concentrated through the process of evaporation [at 122–131 °F (50–55 °C)] in a vacuum chamber. Either *whole* or *nonfat* milk with 60 % of the water removed is then homogenized, fortified with vitamins A and D, canned, and sterilized in the can [240–245 °F (115–118 °C)] in a pressure canner.

Whole evaporated milk must contain not less than 25 % total milk solids and not less than 7.5 % milk fat. Evaporated nonfat milk must contain not less than 20 % milk solids and no more than 0.5 % milk fat. It must be fortified with 125 and 25 IU of vitamins A and D, respectively.

Milk is increasingly *less* stable with the progression of concentration and heat and it may coagulate, so the stabilization of milk proteins is better assured by preheating (forewarming) milk prior to sterilization at temperatures of 203 °F (95 °C) for 10–20 min. This *forewarming* is designed to denature colloidally dispersed serum proteins and to shift salt balance of calcium chloride and phosphates that are in solution. Disodium phosphate or *carrageenan* may be added to stabilize casein against precipitation (Chap. 5).

As mentioned previously (see section "Safety/ Quality of Milk"), an undesirable browning may occur in canned milk. The high temperature used in processing evaporated milk or a long storage of the product may produce a *light tan* color due to the early stages of the ***Maillard reaction*** between the milk protein and the milk sugar, lactose. This color change is *not* a microbial threat.

CULINARY ALERT! Evaporated milk is reconstituted (rehydrated) at a 1:1 ratio of evaporated milk and water, adding slightly less water than was removed in the 60 % evaporation.

Sweetened condensed milk is concentrated whole or nonfat milk with approximately 60 % of the water removed, and sugar levels of 40–45 % in the finished product. There is a calorie difference in this milk processing, as whole sweetened condensed milk contains no less than 8 % milk fat and 28 % total milk solids, and nonfat contains no more than 0.5 % milk fat and 24 % total milk solids.

Sweetened condensed milk is *pasteurized*, although *not sterilized*, because the *high* sugar content (usually at least 60 % in the water phase) plays a role in preventing bacterial growth. This is due to the *osmotic* effect of the sugar that competes with the bacteria for water and, thus, controls bacterial growth.

Dried Milk

Dried milk powder may be processed from either pasteurized *whole* or, more commonly, from *nonfat* milk. One method of drying involves *spray* drying. Milk is first condensed by removing two-thirds of the water and is typically sprayed into a heated vacuum chamber (spray drying) to dry to less than 5 % moisture levels. The drying process has *no* appreciable effect on the nutritive value of milk (National Dairy Council). Most nonfat dry milk is fortified with vitamins A and D.

Instant nonfat dry milk or *agglomerated* milk has some moisture added back to the spray-dried milk powder. As powder, it is easily pourable and dispersible in cold water. When reconstituted, the taste is best when the milk is prepared ahead and served well chilled.

CULINARY ALERT! Three and a half ounces (1–1/3 cups) of dried milk powder is needed to yield 1 quart of fluid milk. Nonfat dried milk (NFDM) may be added to foods to increase the protein or calcium content.

> Dry whole milk is pasteurized whole milk with the water removed. It has limited retail distribution—mainly for use in infant feeding and for people without access to fresh milk, such as campers. Dry whole milk is usually sold to chocolate and candy manufacturers.
>
> Tips on Dry Whole Milk: An opened package should be tightly sealed and stored in a cool, dry place. Dry whole milk develops off-flavors if not used soon after opening. (USDA)

In addition to whole or nonfat milk, *buttermilk* and *whey* may also be dried. Whey is of high biological value containing lactalbumins and lactoglobulins, with *one-half* of the protein and slightly *more* lactose than NFDM.

In particular, dried milk is an economical form of milk for shipping. It has an extended shelf life and is useful as an ingredient for addition to numerous other foods.

Cultured Milk/Fermentation

Cultured products are ***fermented*** by the addition of bacterial cultures, such as *Lactobacilli* and *Streptococci*, to fluid dairy products. These harmless bacteria (or bacterial enzymes) induce a chemical change in the organic substrates of milk solids. Lactose is fermented to lactic acid creating a low pH in the process, which

(1) controls both spoilage and pathogenic bacterial growth and (2) causes the casein to coagulate.

In earlier days, warm milk from various animals (cows, sheep, goats, camels) was preserved for several days or weeks, with no need for refrigeration. This was achieved by the addition of a small milk culture from a preceding batch.

Acidified products are produced by *souring* milk with an acid such as lactic, citric, phosphoric, or tartaric acid with or without microorganisms. The addition of lactic acid-producing bacteria is optional, and because cultured and acidified products contain different amounts of lactic acid, they differ in flavor.

The following milk products are examples of some commonly *cultured* milk products:

- ***Buttermilk***
  Traditionally, buttermilk was the liquid that *remained* when cream was churned to form butter. It was a by-product. *Today*, this is *not* the case commercially, because low-fat or skim milk, *not* cream, begins the process. Although its name (*buttermilk*) may mistakenly signify a high-fat content, the opposite is true! It is more correctly named "cultured low-fat milk" or "cultured nonfat milk."

  Buttermilk differs from nonfat milk in that it contains phospholipids and protein from the fat globule membrane, whereas nonfat milk does not. The texture is different as well.
- **Cultured buttermilk**
  Cultured buttermilk is the pasteurized low-fat, nonfat, or whole milk to which a starter culture of *Lactobacilli* and *Streptococci* (*S. lactis*) is added after the mix has been heated and then cooled. These bacteria ferment lactose, producing lactic acid, which clots the milk. Butter flakes or liquid butter, or low levels (0.01–0.15 %) of salt, may be added. *Leuconostoc citrovorum* and *L. destranicum* bacteria, 0.2 % citric acid, or sodium citrate may be added for flavor.
- **Sour cream**
  Traditionally, sour cream was made from heavy (whipping) cream that was soured. *Today*, it is made from pasteurized, homogenized, fresh, *light cream* (approximately 18 % fat) that is coagulated by a method similar to buttermilk (recall that while *buttermilk* starts *with low-fat or skim milk*, *sour cream* production begins with *18 % fat*, *or perhaps cream*). While inoculation and fermentation steps are *similar* to buttermilk production, fermentation is shortened.

  S. lactis and *Leuconostoc* bacteria may be added for flavor, and stabilizers such as gelatin or gums may be present. *Nonfat milk solids* may be *added* to thicken the cream. A bitter taste in sour cream that is stored more than 3–4 weeks may form due to proteolytic bacterial enzyme activity.
- **Yogurt**
  Yogurt is the food produced by culturing one or more of the pasteurized fluid dairy ingredients such as cream, milk, partially skimmed milk, or skim milk (used alone or in combination depending on the desired fat content) with a bacteria culture. In industrialized regions of the world, yogurt is made with cow's milk.

  Treatment of the milk is that it is both pasteurized and homogenized *before* the addition of a starter which contains the lactic acid-producing bacteria, *L. bulgaricus* and *S. thermophilus*. The process used to make yogurt is similar to buttermilk and sour cream, although the incubation temperature and types of bacteria are different.

  Denaturing proteins (unfolding the native chains or globular shape) becomes important for digestion and for yogurt production wherein the whey proteins bind water and provide a characteristic yogurt texture.

  Yogurt may be made using whole, low-fat, or skim milk. The formulation may include nonfat dry milk (NFDM) or condensed skim milk to boost its solids. It contains not less than 8.5 % MSNF and not less than 3.25 % milk fat. Or it may be prepared to be a reduced- or low-fat yogurt and have levels of 0.5–2.0 % milk fat or less. Other optional ingredients include buttermilk, whey, lactose, lactalbumins, lactoglobulins, or whey modified by partial or complete removal of lactose and/or minerals to increase the nonfat solid contents of the food. New research and development continues to explore additional optional ingredients.

Microorganisms in yogurt exist in a *friendly* form, known as *probiotic flora*. Such probiotic yogurt, with *Lactobacillus* and *Bifidobacterium*, is able to survive destruction during gastrointestinal (GI) passage and offer health benefits such as immune stimulation and positive balance to the GI microflora (Hollingsworth 2001). The Food and Agriculture Organization of the United Nations (FAO) defines probiotics as "live microorganisms administered in adequate amounts which confer a beneficial health effect on the host" (FAO). Most probiotics are bacteria, one is a yeast—*Saccharomyces boulardii* (Hollingsworth 2001).

The National Yogurt Association's "live and active cultures" seal indicates that the yogurt contains at least 100 million *L. acidophilus* bacteria per gram at the time it is manufactured, although this number diminishes with time and the microbial enzyme lactase.

Frozen yogurt may contain stabilizers for freezer stability, sugar, and added milk solids. The different types of yogurt, including sundae-style or, the blended, Swiss yogurt, are cultured and stored in different manners. Nutritive or nonnutritive sweeteners may be added, as well as flavoring agents, color additives, and stabilizers such as gelatin, gums, and pectin (Chap. 17).

- **Acidophilus milk**
  Acidophilus milk is a cultured product made from pasteurized low-fat, nonfat, or whole milk. *Lactobacillus acidophilus* is added and incubated at 99 °F (37 °C). Although *not* proven yet, a possible *benefit* of consumption is that ingestion can produce a number of B vitamins, thereby replacing what may have been destroyed during antibiotic treatment. A variation of this is sweet acidophilus milk. This sweet version has culture added, however is not incubated. It is thought to be therapeutic without the characteristic high acidity and flavor.

  Acidophilus produces the enzyme lactase and helps correct the symptoms of lactose intolerance. It is thought that lactase in combination with *L. acidophilus* is enabled to pass successfully through the stomach acids and reach the small intestine where it functions in lactose digestion, preventing the discomfort experienced by those individuals who are lactose intolerant and unable to digest lactose (National Dairy Council).
- **Kefir**
  Kefir is another, less well-known, fermented, probiotic milk product. It contains numerous bacteria including *Lactobacillus caucasicus* and the yeasts *Saccharomyces kefir* and *Torula kefir*. As well, it is slightly bubbly due to the fermentation process, and it may therefore contain a small amount—approximately 1 %—of alcohol.

  Fermented dairy products have been and *are* used routinely throughout the world—it is a way of life and there is nothing novel about it. Yogurts, smoothies, and a plethora of flavors may be created using kefir. Each introduces live bacteria for good gut health. "… kefir in particular … adding excitement to the drinkable yogurt shelf." The lumps in kefir "grains" are not grains, but, rather, are "little clumps of bacteria, yeasts, sugars, proteins and lipids" (Decker 2012).

  "Prebiotics are nondigestible carbohydrates that act as food for probiotics. When probiotics and prebiotics are combined, they form a synbiotic [the term 'synbiotic' should be used only if the net health benefit is synergistic—the United Nations Food & Agriculture Organization (FAO)]. Fermented dairy products, such as yogurt and kefir, are considered synbiotic because they contain live bacteria and the fuel they need to thrive.

  Probiotics are found in foods such as yogurt, while prebiotics are found in whole grains, bananas, onions, garlic, honey and artichokes. In addition, probiotics and prebiotics are added to some foods and available as dietary supplements" (http://www.mayoclinic.com).

Additional specialty types of milk include low-sodium, lactose-reduced milk, calcium-fortified, as well as flavored milks, and shakes. Non-milks such as rice and soy "milk" are also consumed. The latter are especially useful to persons who are lactose intolerant.

Other Milk Products

Butter

Butter is a concentrated form of fluid milk, produced through churning of pasteurized cream. ***Churning*** involves agitation that breaks fat globule membranes so the emulsion breaks, fat coalesces, and water (buttermilk) escapes. Emulsions may be of two types. The original 20/80 *oil-in-water* type of emulsion of milk becomes a 20/80 *water-in-oil* emulsion. Milk is churned to form butter and the watery buttermilk. Butter may have a yellow color due to the fat-soluble animal pigment, carotene, or an additive.

> Butter is made by churning pasteurized cream. Federal law requires that it contain at least 80 percent milkfat. Salt and coloring may be added. Nutritionally, butter is a fat; one tablespoon contains 12 grams total fat, 7 grams saturated fatty acids, 31 milligrams cholesterol, and 100 calories. Whipped butter is regular butter whipped for easier spreading. Whipping increases the amount of air in butter and increases the volume of butter per pound. The USDA grade shield on butter packages means that butter has been tested and graded by experienced government graders. In addition to checking the quality of the butter, the graders also test its keeping ability. (USDA)

Today, there are various blends of butter and margarine in the market. The fat composition and taste differ from the original. Margarine, or oleomargarine, is the food in plastic form or liquid emulsion containing not less than 80 % fat. It may be produced from water and/or milk and/or milk product, unsalted, or lactose-free. It contains vitamin A and may contain vitamin D.

Sweet cream butter is made by the addition of *S. diacetylactis*, which ferments the citrate in milk to acetaldehyde, acetic acid, and diacetyl, the last being the major flavor compound of butter. Commercially, it may contain salt, yet is known as "sweet cream" butter, because today, the butter is prepared from sweet, not the traditional soured cream. The USDA grade AA is of superior quality, USDA grade A is very good, and grade B is standard.

Spreads contain a higher percentage of water and may not be suitable for some baking and cooking applications.

Cream

> Cream means cream, reconstituted cream, dry cream, and plastic cream. Water, in a sufficient quantity to reconstitute concentrated and dry forms, may be added. (FDA)

Cream is the high-fat component separated from whole milk as a result of the creaming process. It has a higher proportion of fat droplets to milk than regular fluid milk, and according to federal standards of identity, cream must contain *18 % milk fat* or more. Due to this high-fat content of cream compared to milk, some yellow, fat-soluble pigments may be apparent. Some fats are naturally small and do not coalesce.

Various liquid creams available for use in foods include the following:

- Light (coffee) cream—18–30 % butterfat
- Light whipping cream—30–36 % butterfat
- Heavy cream—36 % butterfat, minimum
- "Half-and-Half" cream diluted with nonfat milk—10.5 % butterfat
- Whipping cream packaged under pressure in aerosol cans—may be nonfat or contain various levels of fat, sugar, flavoring, emulsifiers, and a stabilizer

Ice Cream

Ice cream is sometimes referred to as an "indulgent" food, meaning that while fat is reduced elsewhere in the diet, ice cream consumption may not decrease! While ice mixes were enjoyed for centuries prior to this, the first commercial, wholesale ice cream was manufactured in 1851, in Baltimore, MD.

Ice cream is a food produced by freezing, while stirring a pasteurized mix containing *dairy* product. The mix consists of one or more dairy ingredients such as cream, milk, skim milk, sweet cream buttermilk or sweetened condensed milk, and optional caseinates. *In addition* to the dairy ingredient, sherbet, low-fat ice cream, and ice creams contain other ingredients. Typically, sugar (sucrose, dextrose, which flavors and depresses the freezing point), cookies, eggs, fruit, nuts, and other ingredients such as coloring or flavoring agents, emulsifiers [such as egg yolks, polysorbate 80 (a sorbitol ester consisting of a glucose molecule bound to the fatty acid, oleic acid), or mono- and diglycerides], stabilizers (gelatin, vegetable gum), and water are added.

The ice cream mix is subject to pasteurization, homogenization, holding (for aging), and quick freezing. Slow freezing creates larger ice crystals. Air is naturally incorporated into an ice cream mixture by agitation, although excessive air may *not* be whipped into a mix as specified by federal and state standards. The increase in volume due to air is ***overrun*** and is calculated as

$$\begin{aligned}\%\ \text{Overrun} &= (\text{Volume of ice cream} \\ &\quad - \text{Volume of mix}) \times 100 \\ &= \text{Volume of mix}\end{aligned}$$

For instance, if a 1-gallon container of ice cream contains an equal measure of ice cream mix and air, it has 100 % overrun. Overrun in ice creams may range from 60 % to greater than 100 %.

Ice cream contains not less than 10 % milk fat, nor less than 10 % MSNF, except when it contains milk fat at 1 % increments above the 10 % minimum.

Low-fat ice cream (formerly ice milk) contains less fat and more MSNF, and deluxe ice cream contains more milk fat and less MSNF. Other frozen desserts may include milk and varying percentages of milk fat or perhaps a fat substitute.

Blended milk products are fruit juices and milk, which may contain added lactic acid, or caffeine, plus other ingredients, and may be prepared using herb teas and additional sugars.

Sherbet contains 1–2 % milk fat and 2–5 % total milk solids. A greater amount of sugar and less air (hence 30–40 % overrun) than ice cream are standard.

Percent milk fat	Minimum percent MSNF
10	10
11	9
12	8
13	7
14	6

Whey

Whey has previously been discussed as the aqueous (serum) protein in milk, yet it warrants further discussion due to its *increasing* use in consumer products. Research is ongoing to target separating milk serum proteins from liquid milk prior to cheesemaking. Some cheese such as ricotta cheese may be made *partially* of whey.

Whey comprises approximately *20 %* of the protein in milk. It contains the albumins and globulins, the majority of *lactose*, and the water-soluble nutrients, such as riboflavin. Whey is the *by-product* of cheesemaking, the liquid that remains after curds are formed and drained (recall the nursery rhyme Little Miss Muffet—eating her curds and whey!). A tremendous quantity of cheese is manufactured, and, currently, more satisfactory ways of using whey are being explored.

Whey is a nutritious product. It may also be used in beverages, frozen dairy desserts, and baked goods. In a dried form, it may have useful applications as an emulsifier and in providing extra protein to foods. Whey also has foaming and gelling applications. Yet, because it contains lactose, which the majority of the world cannot digest (see section "Lactose Intolerance"), it *cannot* be used in worldwide feeding.

Whey begins to precipitate at temperatures below the coagulation temperature of casein, yet is not precipitated at a pH of 4.6 or by rennin, as is casein. Evidence of whey precipitation is seen when the lactalbumin coagulum (as well as calcium phosphate) sticks to the bottom of the pan and scorches.

In addition to some uses previously listed, whey is concentrated by ultrafiltration to yield *whey protein concentrates* (WPCs). WPC/whey protein isolate (WPI) is also used in sports supplements and bars due to their high nutritional value; WPCs are frequently added to yogurt and dried for use in such items as coffee whitener, whipped toppings, meringue, fruit beverages, chocolate drinks, and processed meats.

Further purification steps may be added to yield WPIs. For example, WPIs are used in infant formulas, and whey refinery may yield proteins used to fortify clear bottled drinks, including sodas. Fractionation in the whey refining process could lead to products without phenylalanine and thus to products with useful ingredients to people with phenylketonuria (PKU) (Food Eng 2000a).

Cooking Applications

Cooking applications subsequent to the mild denaturation or change in molecular structure of proteins may form cross-links and coagulate milk. ***Coagulation*** and precipitation of clumps or aggregates may occur with heat or when acid, enzymes, or salts are in a formulation. In more severe heat, acid, enzyme, or salt treatment, unwelcome curdling may be expected to occur. Some of these effects are as follows:

- **Heat**: Heat, especially direct or high heat, may *denature*, *coagulate*, *or curdle* milk. Slow, *low*, or moderate heat such as indirect heating over a water bath should be used for milk-based products. Increasing temperatures and length of heating may break the fat emulsion if the protein film around the fat globules breaks. Thus, the fat will coalesce. *High* heat also forms greater amounts of coagulum at the bottom of the pan than low heat.

  The *same* calcium phosphate compound that forms at the bottom of the pan by scorching also forms a skin (scum or film) at the surface of the food as water evaporates. This surface skin may "hold in" heat and lead to a boilover of the milk product subjected to heat. Prevention includes use of a pan lid or surface application of an agent such as fat.

CULINARY ALERT! Cooking with a cover is recommended in order to prevent skin formation. Stirring constantly also helps avoid protein precipitation on the sides of the cooking vessel.

- **Acid**: Acid may come from a variety of sources. It be *added* to food or be a *part* of a food, or it may be produced by bacteria. It coagulates milk mixtures by forming unstable *casein* proteins. Casein precipitates at a pH of approximately 4.6 (recall that *whey* proteins are not precipitated by acid). Use of a white sauce may control precipitation.
- **Enzyme coagulation**: As will be discussed in the chapter section on "Cheese," *several* sources of enzymes are responsible for coagulation and curd formation—animal, plant, or microbial enzymes. However, the *primary* enzyme used to coagulate milk in cheese or ice cream is rennin (commercially known as rennet).

  Rennin requires a slightly acidic environment and functions best at temperatures of 104–108 °F (40–42 °C), rather than high temperatures. Calcium is retained if the coagulation of milk is achieved by rennin rather than acid (e.g., some custard-like desserts and cottage cheese).
- **Polyphenolic compound coagulation**: *Phenolic* compounds (formerly called tannins) are in some plant materials including fruits and vegetables (e.g., potatoes, tomatoes), tea, and coffee, and they coagulate milk. Although baking soda (alkali) may be added to milk

combinations to shift the pH and control curdling, it is not recommended, as it destroys vitamin C in the product. Low heat and a gelatinized starch buffer (white sauce) may be used for controlling this undesirable coagulation.

- **Salt coagulation**: *Calcium* and *phosphorus salts* present in milk are less soluble with heat and may coagulate milk protein. Salty foods such as ham as well as some vegetables and salt flavorings that are added to milk frequently may cause the milk to curdle. As with acid-cause coagulation, a gelatinized starch buffer is used to prevent undesirable precipitation.

Fig. 11.1 Cheeses (courtesy of SYSCO® Incorporated)

Cheese

Cheese as defined by the FDA is "a product made from curd obtained from the whole, partly skimmed, or skimmed milk of cows, or from milk of other animals, with or without added cream, by coagulating with rennet, lactic acid, or other suitable enzyme or acid, and with or without further treatment of the separated curd by heat or pressure, or by means of ripening ferments, special molds, or seasoning" (FDA).

With a look at an amount of US cheese consumption over 25 years, beginning in 1985, the per capita cheese rose steadily from 22.5 lb in 1985 to a projected 34.9 lb (Wisconsin Milk Marketing Board).

Cheese (Fig. 11.1) is a concentrated form of milk that contains casein; various percentages of fat, primarily saturated fat; mineral salts; and a small portion of milk serum (whey proteins, lactose, and water-soluble vitamins). It is the curd that forms as a result of casein coagulation by the enzyme rennin (also known as chymosin) or lactic acid. It requires approximately 10 lb of milk to make a pound of cheese.

"Chymosin, known also as rennin, is a proteolytic enzyme synthesized by chief cells in the stomach. Its role in digestion is to curdle or coagulate milk in the stomach, a process of considerable importance in the very young animal. If milk were not coagulated, it would rapidly flow through the stomach and miss the opportunity for initial digestion of its proteins.

"Chymosin efficiently converts liquid milk to a semisolid like cottage cheese, allowing it to be retained for longer periods in the stomach. Chymosin secretion is maximal during the first few days after birth, and declines thereafter, replaced in effect by secretion of pepsin as the major gastric protease.

In days gone by, chymosin was extracted from dried calf stomachs for this purpose. Presently, the cheesemaking industry has expanded beyond the supply of available young calves. Many proteases are able to coagulate milk by converting casein to paracasein; and alternatives to chymosin are readily available. "Rennet" is the name given to any enzymatic preparation that clots milk."

Animal (calf, bovine pepsin), plant (papain), and microbial protease *enzymes* clot milk to form curds. Genetic engineering of bacteria has produced new options. Cheesemaking typically uses rennin and pepsin. Rennin produces clots that are rich in calcium (although slightly tougher curds form with rennin than lactic acid).

- ***Rennin*** is from the stomach of milk-fed *calves*. Although rennin is active at neutral pH, the enzyme clots milk much faster in acidic conditions, such as when lactic acid is used.

Biotechnology has enabled the *specific gene* that produces rennin to be reproduced in *bacteria without* extracts from the calves' stomach. Rennet (the commercial name for rennin) is then produced through fermentation. In fact, half of rennet in cheese production is produced through fermentation (IFIC).

- *Pepsin* is from the stomach of *pigs* (swine).
- *Proteases* from fungi.
- *Plant enzymes* such as *papain* (from papaya) and *ficin* (from figs) may be used by industry to clot milk casein and form some cheeses.

In general, cheese is classified according to (1) the moisture content, producing either very hard, hard, semisoft, or soft cheeses, and (2) the kind and extent of ripening. A brief explanation appears below.

Moisture content
- *Very hard cheese*—e.g., Parmesan and Romano.
- *Hard cheese contains 30–40 % water. It has very tiny fat globules and is a near-perfect emulsion.* For example, cheddar, Colby, Gouda, and Swiss cheese.
- *Semisoft cheese*—blue, feta, Monterey Jack, mozzarella, Muenster cheese, and provolone cheese.
- *Soft cheese* contains 40–75 % water and has large fat globules. It is only slightly emulsified. For example, Brie, Camembert, ricotta, and cottage cheese.

Ripening

Ripening may require 2–12 months. In that time, the changes involve the following:

- *Carbohydrate* lactose is fermented by lactase to lactic acid.
- *Fat* is hydrolyzed by lipase.
- *Protein* undergoes mild proteolysis to amino acids by rennin.

Ripening refers to the *chemical and physical changes* that occur in the cheese in the time between curd precipitation and satisfactory completion of texture, flavor, aroma, and color development. Ripening modifies the characteristics mentioned, as well as continuing to ferment residual lactose.

First, milk proteins are coagulated with enzymes (rennet) and acids. Then, aging or ripening by bacteria or mold occurs. It may be due to bacteria, bacterial enzymes (chiefly rennin), or the fungus mold and yeast. Some example follows:

- Cheeses, such as cottage cheese or cream cheese, are *not* ripened. Other popular unripened cheeses include feta cheese and ricotta.
- Cheeses may be *ripened with bacteria*. Examples include cheddar cheese, Colby, Parmesan, and Swiss cheese. For example, the holes or eye formation in Swiss cheese is evidence of gas-producing bacteria that exist throughout the interior of the cheese.
- Camembert and Brie, for example, are *ripened by mold* that is sprayed onto the surface of the cheese, or mold may be introduced internally as in the *ripening* of blue cheese that is inoculated with *Penicillium roqueforti*.

According to USDA preliminary 2011 statistics, the average personal consumption rose from 29.8 lb per capita in 2000 to 34.9 lb in 2011 (USDA). In descending order, American, cheddar, and mozzarella cheese are by far the leaders in sales, followed by a distant Monterey Jack, Swiss, and Colby cheese. Many American kitchens also contain Parmesan and perhaps blue cheese.

> Cheese production and markets have emerged as important elements of the dairy industry over the past three decades. Supply-and-use analysis shows an upward trend in total cheese consumption over the past three decades. Nielsen 2005 retail Homescan data were used to analyze cheese consumption by location as well as by income, age, and racial/ethnic groups. . . .To the extent that increases in consumers' food expenditure translate into more cheese purchases, it is expected that total cheese consumption will continue to rise. However, changes in the demographic profile of the U.S. population may somewhat slow future growth. USDA Outlook No. (LDPM-193-01) 19 pp, August 2010 (Davis et al. 2010)

In the United States, the FDA has requirements for specific standardized cheese that must be followed by manufacturers, packers, and distributors. For some cheese varieties, a starter culture is used.

Curd development begins as a starter culture is added to milk. Once a curd has formed, it is cut, cooked to shrink the curd, and drained of any remaining whey (syneresis). Next, it is salted to provide flavor, draw whey from the curd, and retard microbial growth. The curd is then pressed and fermented with various microorganisms at 40–55 °F (4–13 °C).

Cottage cheese is an example of a cheese that may be made without bacteria or yeast, however with lactic acid. The origins were not in industry, yet rather individual "cottages." Thus, the name! Cottage cheese is a no/low-fat, soft, acid cheese formed by coagulation of casein with lactic acid. It is made from pasteurized skim milk, to which is added *either* lactic acid or a bacterial culture that produces lactic acid to reduce the pH to 4.6.

Cheese is cut and packaged under hundreds of names worldwide. Despite the abundance of names given to various cheeses throughout the world, there are only approximately 18 types that differ in flavor and texture (Potter and Hotchkiss 1998). These types are listed as follows:

- Brick (USA)—semisoft, ripened primarily by bacteria
- Camembert (France)—soft, mold externally applied (*Oidium lactis* and then *P. camemberti*); thin edible crust
- Cheddar (England)—hard, bacteria ripened (*S. lactis and S. cremoris*); most common cheese used for cooking in the United States, colored by annatto (a seed pod extract)
- Cottage cheese—soft, unripened; creamed, low-fat, nonfat, or dry curd
- Cream cheese (USA)—soft, unripened; may be flavored
- Edam (the Netherlands)—hard, ripened; ball shaped with a red paraffin coating
- Gouda (the Netherlands)—semisoft to hard, ripened; similar to Edam
- Hand—soft
- Limburger (Belgium)—soft, surface bacteria ripened (Bacterium linens)
- Neufchatel (France)—soft, unripened in the United States; ripened in France
- Parmesan (Italy)—hard, bacteria ripened
- Provolone (Italy)—hard, ripened
- Romano (Italy)—very hard, ripened
- Roquefort (France)—semisoft, internally mold ripened (*P. roqueforti*)
- Sapsago (Switzerland)—very hard, ripened by bacteria
- Swiss, Emmentaler (Switzerland)—hard, ripened by gas-forming bacteria (*S. lactis* or *S. cremoris* and *S. thermophilus*, *S. bulgaricus*, and *P. shermani*)
- Trappist—semisoft, ripened by bacteria and surface microorganisms
- Whey cheeses, such as ricotta (Italy), which may be a combination of whole and low-fat milk or whey; coagulated by heating, not rennin (Potter and Hotchkiss 1998; some definition in fourth and fifth edn.)

More details of the types of cheese available to the consumer are listed and explained below:

- *Natural cheese* is the curd of precipitated casein—either ripened or unripened. It may be overcoagulated and allow water to be squeezed out, or the fat emulsion to break when exposed to *high* heat, in which case it shows a separated appearance and stringy texture. Therefore, *low* heat should be used when cooking with natural cheese.

- *Pasteurized process*(*ed*) *cheese* is the most common cheese produced in the United States. By FDA ruling, it is "prepared by comminuting and mixing, with the aid of heat, one or more cheeses of the same, or two or more varieties, except cream cheese, neufchatel cheese, cottage cheese, low-fat cottage cheese, cottage cheese dry curd, cook cheese, hard grating cheese, semisoft, part-skim cheese, part-skim spiced cheese, and skim milk cheese for manufacturing with an emulsifying agent . . . into a homogeneous plastic mass" (CFR 21).

  The mixture is pasteurized (which halts ripening and its flavor development) for 3 min at 150 °F (66 °C), and salt is added. An emulsifier such as disodium phosphate or sodium citrate is incorporated to bind the calcium and produce a more soluble, homogeneous, and smooth cheese that can withstand higher heat than natural cheese, without coagulating. The melted cheese is placed in jars or molds such as foil-lined cardboard boxes or single-slice plastic wrap.

  This cheese may also contain an optional mold-inhibiting ingredient consisting of not more than 0.2 % by weight of sorbic acid, potassium sorbate, sodium sorbate, or any combination of two or more of these or consisting of not more than 0.3 % by weight of sodium propionate, calcium propionate, or a combination of sodium and calcium propionate. It may contain pimentos, fruits, vegetables, or meats.

  The moisture content of a process cheese made from a *single variety* of cheese is not more than 1 % greater than the maximum moisture content prescribed by the definition and standard of identity, for the variety of cheese used, if there is one. In no case is the moisture more than 43 % (except 40 % for process washed curd and process Colby cheese and 44 % process Swiss and Gruyere).

  The moisture content of a process cheese made from *two or more* varieties of cheese, as opposed to the aforementioned one is not more than 1 % greater than the arithmetical average of the maximum moisture contents prescribed by the definitions and standards of identity, if there is one, for the cheeses used. In no case is the moisture content more than 43 % (40 % cheddar, Colby, 44 % Swiss and Gruyere).

  The fat content of process cheese made from a single variety of cheese is not less than the minimum prescribed by the definition and standard of identity for the variety of cheese used, and in no case is less than 47 % (except process Swiss 43 % and process Gruyere 45 %). The fat content of process cheese made from two or more varieties of cheese is not less than the arithmetical average of the two cheeses, as described above, and in no case is less than 47 % (except the mixture of Swiss and Gruyere 45 %).

- *Pasteurized process*(*ed*) *cheese food* is comminuted and mixed and contains not less than 51 % cheese by weight. The moisture is not more than 44 %, and the fat content is not less than 23 %. Thus, it contains less cheese and more moisture than process cheese. It may contain cream, milk, nonfat milk, NDM, whey, and other color or flavoring agents. It has a soft texture and melts easily.

  An emulsifying agent may be added in such quantity that the weight of the solids of such an emulsifying agent is not more than 3 % of the weight of the pasteurized process cheese food (FDA).

- *Pasteurized process cheese spread* is comminuted and mixed. It has a moisture content of 44–60 % and a milk fat level of not less than 20 %. Therefore, it has more moisture and less fat than processed cheese food and can be spread. Gelatin and gums such as carob bean, cellulose gum (carboxymethylcellulose), guar, tragacanth, and xanthan, as well as carrageenan, may be added if such substances are not more than 0.8 % of the weight of the finished product

(FDA). Sodium may be added to retain moisture, and sugar or corn syrup may be added for sweetness.

- *Cold-pack cheese* preparation involves grinding and mixing natural cheese without heat. The moisture content of a cold-pack cheese made from a single variety of cheese is not more than the maximum prescribed for the variety of cheese used (if there is a standard of identity), and the fat content is not less than the minimum prescribed for that cheese, yet is not less than 47 % (except 43 % cold-pack Swiss and 45 % Gruyere).

Although cold-pack cheeses may contain various flavor combinations, manufacturers have/have used the technology to create custom-colored and custom-flavored specialty cheeses as needed (Food Eng 2000b). When made from two or more varieties of cheese, the moisture content should be the arithmetical average of the maximum of the two cheeses, as prescribed by the definition or standard of identity, yet in no case more than 42 %. The fat content is not less than the arithmetical average of the minimum percent of fat prescribed for the cheeses, if there is a standard of identity or definition, but in no case less than 47 % (cold-pack Swiss and Gruyere 45 %).

The lactose content of ripened cheese *decreases* during ripening and is virtually *absent* in several weeks. It is the whey that contains lactose, which some individuals cannot consume (lactose intolerance). The majority of vitamins and minerals remain after ripening, some protein is hydrolyzed by rennin or proteases, and some fat is digested. Grades of US grade AA and A are assigned to some commonly consumed cheeses such as cheddar and Swiss cheese.

CULINARY ALERT! Tips for lengthening shelf life of cheese involve cold storage and lowering the pH. This is achieved by refrigeration and wrapping in a vinegar-soaked cheesecloth.

If mold forms on the cheese, it may not be acceptable to the would-be consumer. Yet, the rule of thumb is not necessarily to discard the entire piece of cheese. Rather, any apparent mold should be cut off deeper than what is seen in order to cut out the roots. The mold may produce a toxin. (Keep in mind that mold is acceptable in certain cheeses such as blue cheese.)

CULINARY ALERT! Blue cheese is made from cow's milk; Roquefort cheese is made from sheep milk. If other cheeses show mold, they can be consumed if mold is cut away deeper than what can be seen. It is recommended to cut off ¼ to 1 in. of this moldy product.

According to a research study by Oregon State University, "Imitation cheese is made from vegetable oil: it is less expensive, but also has less flavor and doesn't melt well. For the record, *Velveeta*® is pasteurized process cheese spread and *Velveeta Light*® is pasteurized process cheese product. *Cheez Whiz*® is labeled as pasteurized process cheese sauce, although that type isn't noted in the *Code of Federal Regulations*" (OSU).

Milk Substitutes Imitation Milk Products

Milk substitute and imitation milk products were officially defined in 1973. At that time, the FDA differentiated between *substitute* and *imitation* products by establishing regulations regarding the use of the two names. More details follow each introduction:

A milk ***substitute*** product is one that resembles the traditional product and is nutritionally equal. A substitute is pasteurized, homogenized, and packaged like milk. It is more economical than real dairy products because it does not contain the costly butterfat.

Filled Milk

Filled milk is an example of milk ***substitute*** and *does not contain milk fat*. It consists of a *vegetable* fat or oil, and nonfat milk solids, so it is a not a substitute for persons with milk allergies. The vegetable fat has *traditionally* been coconut oil, although it may be partially hydrogenated corn, cottonseed, palm, or soy oil. Oil, water, an emulsifier such as monoglycerides or diglycerides, color such as carotene, and flavoring may be added. Filled milk contains no cholesterol.

An ***imitation milk*** product may look and taste like the traditional product, yet is nutritionally inferior. Specifying the term “imitation” on labels is no longer a legal requirement.

Imitation Milk

Imitation milk usually contains *no* milk products at all—*no* milk fat or milk solids. It is composed of water, vegetable oil, corn syrup, sugar, sodium caseinate, or soy, and stabilizers and emulsifiers. Vitamins and minerals may be added to the product to improve the nutritional value. Again, the term “imitation” on labels is no longer a legal requirement.

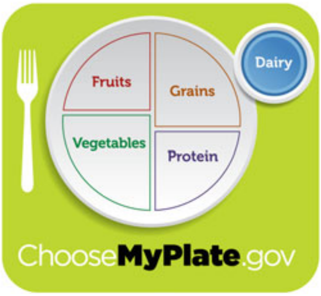
Food items that are available in the marketplace, including nondairy dry and liquid creamer, may fit into these above categories.

CULINARY ALERT! Milk and milk products with the “Real” symbol on the package indicate that the product is made from real dairy products, not substitutes or imitations.

CULINARY ALERT! Flavored “milk,” “butter,” “cream cheese,” whipped “cream,” and other imitation products are readily available in the marketplace. Nondairy “creamers” or whiteners are prevalent in fluid and dehydrated form.

Nutritive Value of Milk and Milk Products

The 1996 FDA ruling for nutritive value of milk and milk products *revoked* the “standard of identity” (prescribed formulation or recipe that the manufacturer needed to follow). The nutrient claims such as “fat-free” and others similar to those carried by other products became the *rule* for dairy labels.



Grains Group	Vegetable Group	Fruit Group	Dairy Group	Protein Foods Group
Make at least half your grains whole.	**Vary your veggies.**	**Focus on fruits.**	**Get your calcium-rich foods.**	**Go lean with protein.**

Open to some discussion and further research on fats, the current American Heart Association recommendation states that “We recommend that adults and children age 2 and older use milk that’s *low* in dairy fats. This includes fortified fat-free (skim or nonfat) milk, fortified nonfat milk powder, and 1/2 and 1 % low-fat milk. The label on the container should show that the milk has been fortified with *vitamins A and D*. We also recommend buttermilk made from skim milk and canned evaporated skim milk.

10 tips
Nutrition Education Series

got your dairy today?

10 tips to help you eat and drink more fat-free or low-fat dairy foods

The Dairy Group includes milk, yogurt, cheese, and fortified soymilk. They provide calcium, vitamin D, potassium, protein, and other nutrients needed for good health throughout life. Choices should be low-fat or fat-free—to cut calories and saturated fat. How much is needed? Older children, teens, and adults need 3 cups* a day, while children 4 to 8 years old need 2½ cups, and children 2 to 3 years old need 2 cups.

1 “skim” the fat

Drink fat-free (skim) or low-fat (1%) milk. If you currently drink whole milk, gradually switch to lower fat versions. This change cuts calories but doesn’t reduce calcium or other essential nutrients.

2 boost potassium and vitamin D, and cut sodium

Choose fat-free or low-fat milk or yogurt more often than cheese. Milk and yogurt have more potassium and less sodium than most cheeses. Also, almost all milk and many yogurts are fortified with vitamin D.

3 top off your meals

Use fat-free or low-fat milk on cereal and oatmeal. Top fruit salads and baked potatoes with low-fat yogurt instead of higher fat toppings such as sour cream.

4 choose cheeses with less fat

Many cheeses are high in saturated fat. Look for “reduced-fat” or “low-fat” on the label. Try different brands or types to find the one that you like.

5 what about cream cheese?

Regular cream cheese, cream, and butter ***are not*** part of the dairy food group. They are high in saturated fat and have little or no calcium.

6 ingredient switches

When recipes such as dips call for sour cream, substitute plain yogurt. Use fat-free evaporated milk instead of cream, and try ricotta cheese as a substitute for cream cheese.

7 choose sweet dairy foods with care

Flavored milks, fruit yogurts, frozen yogurt, and puddings can contain a lot of added sugars. These added sugars are empty calories. You need the nutrients in dairy foods—not these empty calories.

8 caffeinating?

If so, get your calcium along with your morning caffeine boost. Make or order coffee, a latte, or cappuccino with fat-free or low-fat milk.

9 can’t drink milk?

If you are lactose intolerant, try lactose-free milk, drink smaller amounts of milk at a time, or try soymilk (soy beverage). Check the Nutrition Facts label to be sure your soymilk has about 300 mg of calcium. Calcium in some leafy greens is well absorbed, but eating several cups each day to meet calcium needs may be unrealistic.

10 take care of yourself and your family

Parents who drink milk and eat dairy foods show their kids that it is important. Dairy foods are especially important to build the growing bones of kids and teens. Routinely include low-fat or fat-free dairy foods with meals and snacks—for everyone’s benefit.

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* What counts as a cup in the Dairy Group? 1 cup of milk or yogurt, 1½ ounces of natural cheese, or 2 ounces of processed cheese.

USDA United States Department of Agriculture
Center for Nutrition Policy and Promotion

Go to www.ChooseMyPlate.gov for more information.

DG TipSheet No. 5
June 2011
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> Avoid substitutes that contain *coconut oil*, *palm oil or palm kernel oil*. These oils are very high in *saturated* fats. Saturated fats tend to raise the level of cholesterol in the blood. High blood cholesterol is one of the six major risk factors for heart disease that can be changed, treated or modified. It can also lead to developing other heart and blood vessel diseases (AHA)."

Proteins

High-quality proteins are in milk—casein and whey. According to the American Diabetes Association (ADA) Exchange List, an 8-ounce serving of fluid milk contains 8 g of protein, regardless of fat content.

Several milklike substitutes are available on the market—rice milk, soy milk, and others may be found at the grocery store and specialty stores. Such products meet special allergy and nutrition needs.

Fats and Cholesterol

Labeling changes have served both to benefit processors' creativity, such as in developing "light" milk, and to better assist consumers in lowering their fat and saturated fat intake. As shown above (Types of Milk), a label may state whole milk, reduced fat, or fat-free. The calorie levels differ according to the fat content. For example, whole milk contains 150 calories per 8 ounce and skim milk contains 90 calories per 8 ounce. Cholesterol levels range from 4 to 33 mg per cup.

According to the USDA, milk sales have indicated an increase in the sales of reduced-fat and skim milk, while there has been a decrease in sales of full-fat, whole milk.

Carbohydrates

The carbohydrate content of 8 ounces of milk is 12 g regardless of the level of fat. A discussion of lactose intolerance follows.

Vitamins and Minerals

The fat-soluble vitamins A, D, E, and K are present in whole and some reduced-fat milk. Fortification beyond vitamin A and D is not allowed in current standards of identity. Milk is a major source of riboflavin (B_2) in the diet of many populations. Losses of B_2 may occur due to exposure to sunlight as riboflavin is a photosynthesizer. Milk also contains the amino acid tryptophan, a precursor to niacin. Milk is a good source of the mineral calcium.

No apparent undesirable effect on protein, fat, carbohydrates, minerals, and vitamins B_6, A, D, and E is observed with pasteurization. Vitamin K is slightly diminished, and there is less than 10 % loss of thiamin and vitamin B_{12}.

One 8-ounce cup (240 mL) of whole fluid cow's milk contains the following minerals: potassium, calcium, chlorine, phosphorus, sodium, sulfur, and magnesium. Milk does not contain iron. The composition of milks from different species appears in Table 11.2.

Low-sodium milk may be included in diets with sodium restrictions. Sodium may be reduced from a normal amount of 49 mg to about 2.5 mg/100 g of milk by replacing the sodium with potassium in an ion exchange.

Flavored milks are an alternative to such beverages and may assist in consuming calcium (Johnson et al. 2002).

CULINARY ALERT! There is no appreciable effect on the availability of calcium or protein to humans when normal quantities of *chocolate* are added to milk (National Dairy Council).

FDA Report Summary

The Food and Drug Administration (FDA) is announcing that the International Dairy Foods Association (IDFA) and the National Milk Producers Federation (NMPF) have filed a petition requesting that the Agency amend the standard of identity for milk and 17 other dairy products to provide for the use of any safe and suitable sweetener as an optional ingredient. FDA is issuing this notice to request comments, data, and information about the issues presented in the petition. (FDA 2013)

Last modified on December 26, 2012 is An Overview of U.S. State Milk Laws—http://www.realmilk.com.

Lactose Intolerance

Lactose intolerance is an inability to digest the principal milk sugar, lactose. Many individuals demonstrate a permanent loss of the enzyme used to digest lactose. It may be due to the absence of, or insufficient amount of, lactase, a birth deficit, or physical impairment. Caucasians are among the *few* population groups who can digest lactose.

A reminder: Lactose is a disaccharide of glucose and galactose and represents the slightly less than 5 % carbohydrate that is in milk.

If lactose remains undigested by lactase in the intestine, it is fermented by microflora to form short-chain fatty acids and gases such as carbon dioxide, hydrogen, and, in some individuals, methane. Symptoms of lactose intolerance include flatulence, abdominal pain, and diarrhea due to the high solute concentration of undigested lactose. A correct understanding of tolerable doses may be more liberal than expected. Both the lactose-intolerant individual and the food industry may benefit. Also, acidophilus milk contains the needed enzyme lactase and is readily available at many grocery markets.

Lactose assists in the absorption of calcium, phosphorus, magnesium, zinc, and other minerals from the small intestine brush border. Nondairy "milk" such as rice or soy milk or other imitation milk contains no lactose and may be consumed by individuals with milk allergies and by those who would otherwise not drink milk.

The loss of lactase activity in the intestine affects, to some extent, approximately 75 % of the world's population. Individuals with lactose intolerance may compensate by consuming lactase-treated milk (which reduces lactose by 70 %) or purchase the lactase enzyme and administer it directly to milk prior to consumption. It has been shown that small servings (120 mL = 6 g of lactose) of milk and hard cheeses (less than 2 g of lactose) may be consumed without an increase in intolerance symptoms. Hard cheeses contain less lactose than soft cheeses. Up to 12 g of lactose are tolerated, especially if the individual consumes other foods with the source of lactose.

A quantity of fermented products, such as cheese, is tolerated if lactose has sufficiently been converted to lactic acid. Aged cheese is an example of such food. The lactose content of some milk and milk products is given in Table 11.3.

Safety/Quality of Milk

Safe handling was previously discussed in this chapter.

Milk is a highly perishable substance, high in water, with significant amount of protein and a near-neutral pH (6.6)—the qualities that *support bacteria growth*. Details of sanitation are previously mentioned, but it is important to know about the care and safety of milk. Depending on the ingredients, even nondairy imitation "milks" *may* require refrigeration or freezing comparable to the dairy product that they resemble.

Packaging contains a date on the carton that should be followed for a retail sale. Milk may remain fresh and usable for several days past this "sell-by date" if the following directions, suggested by the Dairy Council, are observed:

Table 11.3 Lactose content of milk and milk products

Type of milk	Weight 1 cup (g)	Average percentage	Grams/cup
Whole milk	244	4.7	11.5
Reduced-fat milk (2 %)	245	4.7	11.5
Low-fat milk (1 %)	245	5	12.3
Nonfat milk	245	5	12.5
Chocolate milk	250	4.5	11.3
Evaporated milk	252	10.3	26.0
Sweetened condensed milk	306	12.9	39.5
Nonfat dry milk (unreconstituted)	120	51.3	61.6
Whole dry milk (unreconstituted)	128	37.5	47.9
Acidophilus milk (nonfat)	245	4.4	10.8
Buttermilk	244	4.3	10.5
Sour cream	230	3.9	8.9
Yogurt (plain)	277	4.4	10.0
Half-and-Half	242	4.2	10.0
Light cream	240	3.9	9.3
Whipping cream	239	2.9	6.9

Source: National Dairy Council

- Use proper containers to protect milk from exposure to sunlight, bright daylight, and strong fluorescent light to prevent the development of off-flavor and a reduction in riboflavin, ascorbic acid, and vitamin B_6 content.
- Store milk at refrigerated temperatures [45 °F (7 °C)] or below as soon as possible after purchase.
- Keep milk containers closed to prevent absorption of other food flavors in the refrigerator. An absorbed flavor alters the taste but the milk is still safe.
- Use milk in the order purchased.
- Serve milk cold.
- Return milk container to the refrigerator immediately to prevent bacterial growth. Temperatures above 45 °F (7 °C) for fluid and cultured milk products for even a few minutes reduce shelf life. Never return unused milk to the original container.
- Keep canned milk in a cool, dry place. Once opened, it should be transferred to a clean opaque container and refrigerated.
- Store dry milk in a cool, dry place and reseal the container after opening. Humidity causes dry milk to lump and may affect flavor and color changes. If such changes occur, the milk should not be consumed. Once reconstituted, dry milk should be treated like any other fluid milk: covered and stored in the refrigerator.
- Serve UHT milk cold and store in the refrigerator after opening.

"In 1924, the United States Public Health Service (USPHS), a branch of the FDA, developed the Standard Milk Ordinance, known today as the Pasteurized Milk Ordinance (PMO). This is a model regulation helping states and municipalities have an effective program to prevent milk borne disease. The PMO contains provisions governing the production, processing, packaging and sale of Grade "A" milk and milk products. It is the basic standard used in the, a program all 50 states, the District of Columbia and U.S. Territories participate in.

Forty-six of the 50 have adopted most or all of the PMO for their own milk safety laws with those states not adopting it passing laws that are similar. California, Pennsylvania, New York and Maryland have not adopted the PMO.

Section 9 of the PMO states in part that, "only Grade 'A' pasteurized, ultra-pasteurized or aseptically processed milk and milk products shall be sold to the final consumer, to restaurants, soda fountains, grocery stores or similar establishments" (http://www.realmilk.com).

How USDA's Dairy Grading Program Works

The **US grade AA or grade A** shield is most commonly found on butter and sometimes on cheddar cheese.

US Extra Grade is the grade name for instant nonfat dry milk of high quality. Processors who use USDA's grading and inspection service may use the official grade name or shield on the package.

The "**Quality Approved**" shield may be used on other dairy products (e.g., cottage cheese) or other cheeses for which no official US grade standards exist if the products have been inspected for quality under USDA's grading and inspection program. USDA

> . . . the composition or milkfat content given for each product (except for butter) is required under FDA regulations. State laws or regulations may differ somewhat from FDA's. The milkfat content of butter is set by a Federal law. FDA has established a regulation that allows a product to deviate from the standard composition in order to qualify for a nutrient content claim. Products such as nonfat sour cream, light eggnog, reduced fat butter, and nonfat cottage cheese fall into this category. (USDA)

Carbohydrate browning reactions with their color and flavor changes are observed in canned or dry milk that has been subject to either long or high-temperature storage. It should be mentioned here that the browning does not indicate contamination or spoilage. Rather, it is the nonenzymatic ***Maillard browning*** or "carbonyl-amine browning" reaction between the free carbonyl group of a reducing sugar and the free amino group of protein.

Marketing Milk

Marketing milk has made use of the National Milk Mustache "got milk?" Campaign. See the Milk Processor Education Program at http://www.milknewsroom.com/index.htm. This site is designed to be a resource for the media to access information about milk research, milk programs, and the National Milk Mustache "got milk?" Campaign.

Conclusion

Milk is the first food of mammals. It contains major nutrients, carbohydrate, fat, and protein, with water being predominant (88 %). The two major proteins in milk are casein and whey, with additional protein found in enzymes. The fat content of milk is designated by law according to the specific product and jurisdiction.

Milk is pasteurized to destroy pathogens and is homogenized to emulsify fat and prevent creaming. Grade A milk must be treated in this manner if subjected to interstate commerce. Milk may be fluid, evaporated, condensed, dried, or cultured and made into butter, cheese, cream, ice cream, or a variety of other products. It is a potentially hazardous food due to its high protein, water activity, and neutral pH and must be kept cold.

Notes

CULINARY ALERT!

Glossary

Buttermilk, cultured Pasteurized low-fat or nonfat milk to which bacteria are added to ferment lactose to the more acidic lactic acid that clots the casein in milk.

Casein Primary protein of milk, colloidally dispersed.

Casein micelles Stable spherical particles in milk containing α_s-, β-, and κ-casein, and also colloidal calcium phosphate. The micelles are stabilized by κ-casein, which exists mainly at the surface; the α_s- and β-casein fractions are located mainly in the interior of the micelles.

Cheese Coagulated product formed from the coagulation of casein by lactic acid or rennin; may be unripened or bacteria ripened; made from concentrated milk.

Churning Agitation breaks fat globule membranes so the emulsion breaks, fat coalesces, and water escapes.

Coagulate The formation of new cross-links subsequent to the denaturation of a protein. This forms a clot, gel, or semisolid material as macromolecules of protein aggregate.

Creaming Fat globules coalesce (less dense than the aqueous phase of milk) and rise to the surface of unhomogenized, whole, and some low-fat milk.

Cultured See fermented.

Evaporated milk Concentrated to remove 60 % of the water of ordinary fluid milk; canned.

Fermented (Cultured) enzymes from microorganisms or acid that reduce the pH and clot milk by breaking down the organic substrates to smaller molecules.

Fortified Increasing the vitamin content of fresh milk to contain vitamins A and D to levels not ordinarily found in milk.

Homogenization Dispersion of an increased number and smaller fat globules to prevent creaming.

Imitation milk Resembles (looks, tastes like) the traditional product but is nutritionally inferior—contains no butterfat or milk products.

Lactose intolerance Inability to digest lactose due to the absence or insufficient level of intestinal lactase enzyme.

Maillard reaction The first step of browning that occurs due to a reaction between the free amino group of an amino acid and a reducing sugar; nonenzymatic browning.

Milk solids nonfat (MSNF) All of the components of milk solids except fat.

Milk substitute Resembles (looks, tastes like) traditional product and is nutritionally equal; contains no butterfat (e.g., filled milk).

Overrun The increase in volume of ice cream over the volume of ice cream mix due to the incorporation of air.

Pasteurization Heat treatment to destroy pathogenic bacteria, fungi (mold and yeast), and most nonpathogenic bacteria.

Rennin Enzyme from the stomach of milk-fed calves used to clot milk and form many cheeses.

Ripening The time between curd precipitation and completion of texture, flavor, and color development in cheese. Lactose is fermented, fat is hydrolyzed, and protein goes through some hydrolysis to amino acids.

Sterilization Temperature higher than that required for pasteurization, which leaves the product free from all bacteria.

Sweetened, condensed milk Concentrated to remove 60 % of the water, contains 40–45 % sugar.

Total milk solids All of the components of milk except for water.

Whey Secondary protein of milk, contained in serum or aqueous solution; contains lactalbumins and lactoglobulins.

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Model FDA Food Code

National Dairy Council. Rosemont, IL

Standards of identity for dairy products—http://milkfacts.info/MilkProcessing/StandardsofIdentity.htm, Part 131—milk and cream—http://www.access.gpo.gov/nara/cfr/waisidx_06/21cfr131_06.html, Part 133—cheeses and related cheese products—http://www.access.gpo.gov/nara/cfr/waisidx_06/21cfr133_06.html, Part 135—frozen desserts—http://www.access.gpo.gov/nara/cfr/waisidx_06/21cfr135_06.html

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