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## 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.

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## 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.

**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.

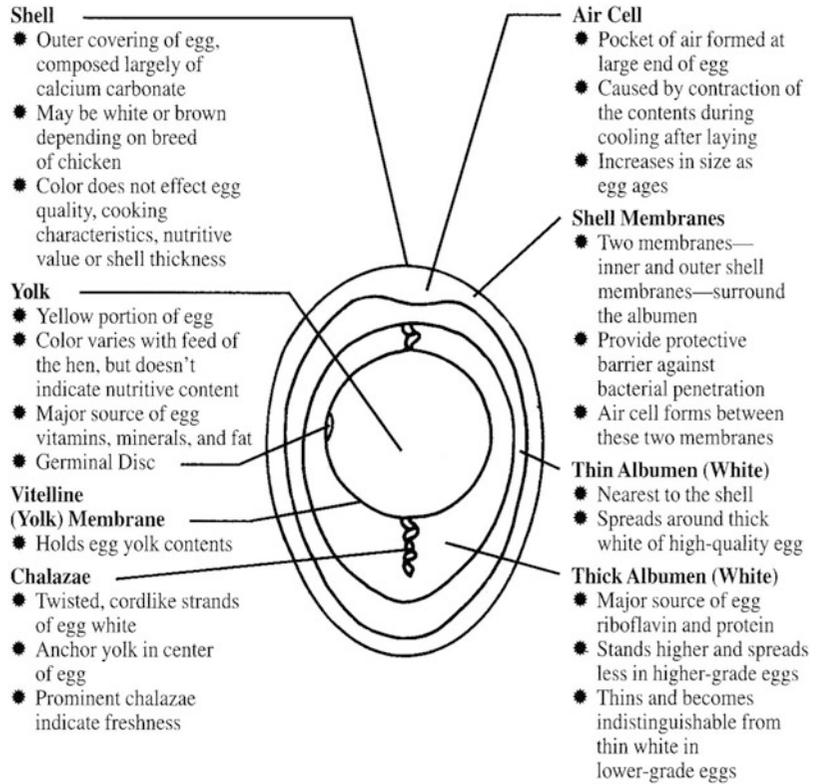
*Surrounding* the yolk is a colorless sac, the **vitelline membrane** (Fig. 10.1). It is continuous with the opaque-colored chalazae (kah-lay-za) cord structure. The chalazae is a ropelike cord that attaches to the yolk vitelline membrane yet is actually found in the albumen, or white. It holds the yolk 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, ovomucoid, 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<sub>2</sub> and moisture losses occur and O<sub>2</sub> 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<sub>2</sub> 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**

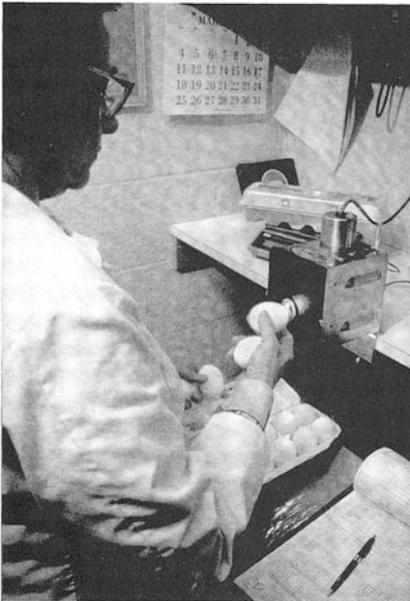
Eggs coagulate and thicken mixtures such as custards and hollandaise sauce

**• 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

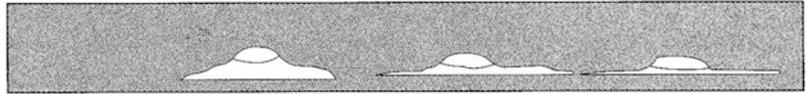
The *air cell*, also known as the *air sac* or *air pocket*, is the empty space formed at the large end of the egg. By definition, it holds oxygen. Initially, there is either *no* air cell or a small one. Then it becomes large and apparent to the eye when the warm egg cools, the egg contents shrink, 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<sub>2</sub> 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.

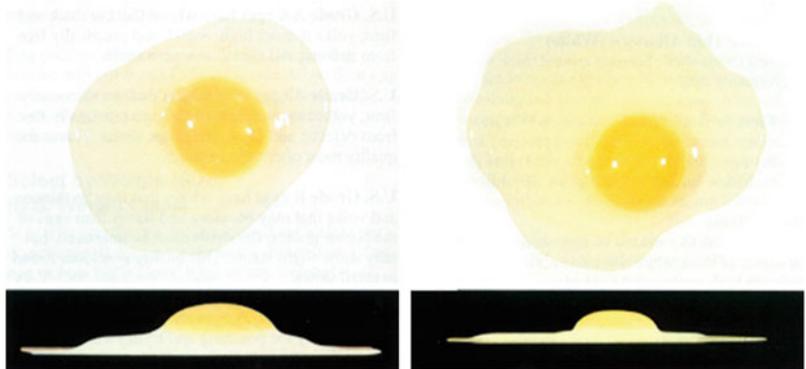
**Fig. 10.5** Grades of eggs  
(Source: California Egg Commission)



	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**

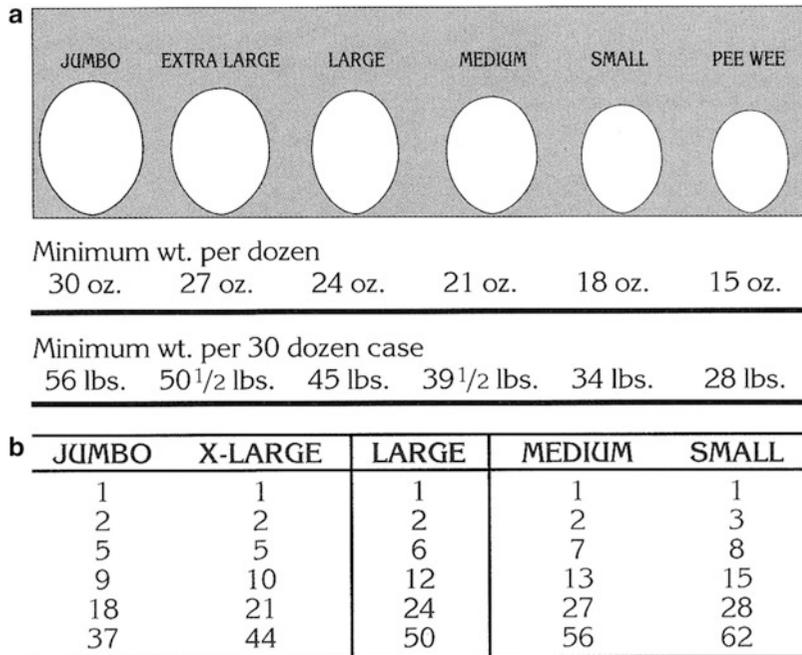
Egg-size comparisons are shown in Fig. 10.7. The USDA does *not* include an evaluation of egg *size* as a part of egg *quality*. USDA

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

**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<sub>2</sub>.

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<sub>2</sub>, 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.

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### 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

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### 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.

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## 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

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.

## **Cooking/Baking Changes**

Cooking typically produce noticeable egg changes, hopefully while keeping a tender, high-quality product. With the expected/

**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

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**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

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**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

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**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

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**Sugar**—The protective effect of sugar on eggs has been discussed

*Early addition*

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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

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*Late addition*

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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)

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**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

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**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

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**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

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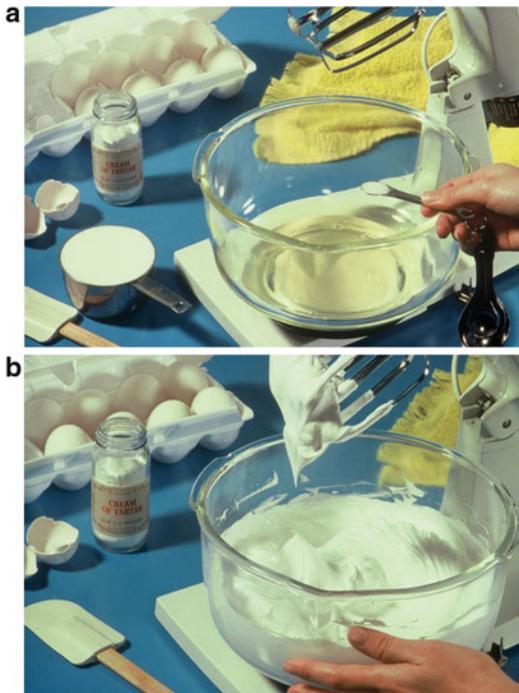
be slightly warmed by placing the appropriate number of separated egg whites in a bowl over warm water. This allows the egg whites to warm up prior to successful whipping.

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 *undercoagulated* (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  $\frac{1}{2}$  to 1 teaspoon of cornstarch to the sugar prior to beating it into the eggs.

**Beading** is apparent in *overcoagulated* (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.

				
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.

### 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.

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.

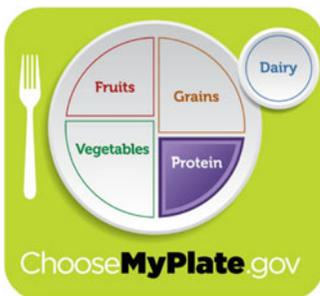
Eggs are a complete protein, with a **biological value** of 100, which indicates that all of the protein is retained by the body. All other protein sources are evaluated against this standard. That is not to say that eggs are “the perfect food.” Persons who follow an ovo-vegetarian diet include eggs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

### Nutritive Value of Eggs



### 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	<ul style="list-style-type: none"> <li>• Small volume of thick and thin whites</li> <li>• No initial additives</li> </ul>
Foamy	<ul style="list-style-type: none"> <li>• Unstable, large air-cell volume, transparent</li> <li>• Bubbles coalesce if beating is halted</li> <li>• Acid coagulates protein around air cell</li> <li>• Add cream of tartar (acid) now</li> </ul>
Soft rounded peaks	<ul style="list-style-type: none"> <li>• Air cells subdivide in size and are whiter</li> <li>• Volume is increased</li> <li>• Add sugar now</li> <li>• May be used for food applications</li> <li>• Used for soft meringue</li> </ul>
Stiff pointed peaks	<ul style="list-style-type: none"> <li>• Many small air cells, volume is increased</li> <li>• Egg protein coagulates around fine air cells</li> <li>• Ready for most food applications</li> <li>• Used for hard meringue</li> </ul>
Dry peak foam	<ul style="list-style-type: none"> <li>• Brittle, inelastic; less volume as air cells break</li> <li>• Denatured, water escapes, <i>flocculated</i></li> <li>• Not as effective as a leavening agent</li> <li>• Overcoagulated, curdled appearance</li> </ul>

**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](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](http://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](mailto: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:



See: TipSheet no. 6 (in Meats)

American Egg Board		
Realities/misconceptions		
Issue	Misconception	Fact
<i>Salmonella</i>	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 <i>Salmonella</i> . 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



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](http://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](http://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.

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## 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 breadings 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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