

Wheat flour is the basic ingredient in almost all types of baked products including yeast and quick breads, cookies, cakes, and pastries. Courtesy of Plycon Press.

# 15

## Basics of Batters and Doughs

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### BASICS OF FLOUR MIXTURES

Breads have been baked as a mainstay of the diet for many civilizations over the centuries. Ancient Egyptians apparently had the ability to make leavened bread more than 5,000 years ago. Today breads take many different shapes and include diverse ingredients, depending upon the particular staple grain available and the cultural preferences of consumers.

Interest in bread has undergone a resurgence as people have become increasingly aware of the nutritional merits of complex carbohydrates and fiber. The enthusiasm for natural foods without preservatives has prompted the bakery industry to market breads containing a variety of whole-grain cereals. Consequently, the standards that people formerly used for selecting breads in the market have undergone some significant changes from the “balloon” loaves of earlier years. This same movement is reflected in the increase in baking bread at home, particularly breads made with mixtures of different flours.

Bread and other baked products, such as cakes, cookies, and pastries, are made using flour as the primary ingredient, which is mixed with a liquid and usually various other ingredients to create a batter or a dough. When these are baked, their structures set so that they can be cut and often may be held in the hand.

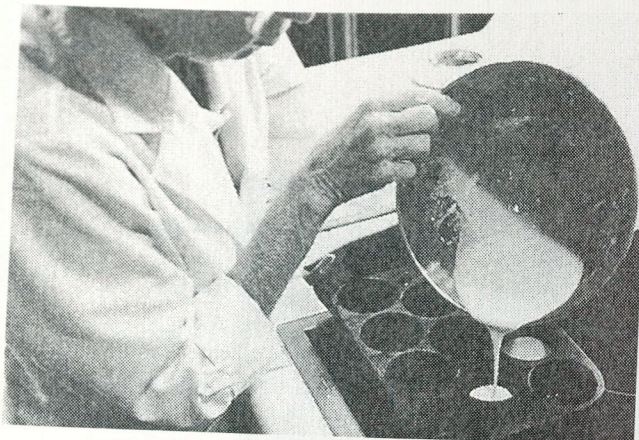
Batters and doughs have varying physical properties because of the different flour-to-liquid ratios in them. Batters fluid enough to be poured (approximately equal parts of liquid and flour) are classified as **pour batters**. Popovers, pancakes, and shortened cakes are baked from pour batters (Figure 15.1). A **soft batter** (made with twice as much flour as liquid) can be dropped from a spoon. Dumplings, some cookies, muffins, and various other quick breads are products made with soft batters (Figure 15.2).

### Key Concepts

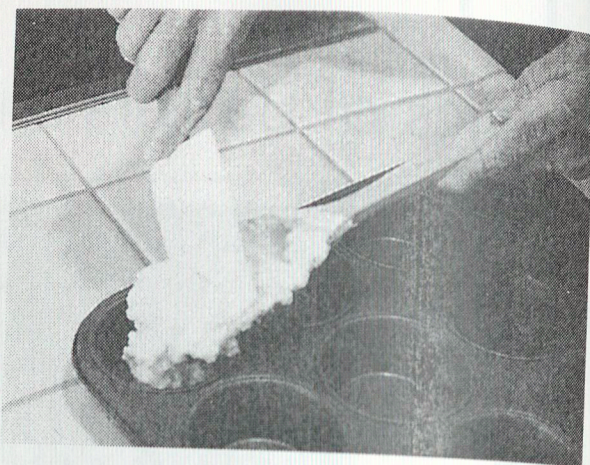
1. Wheat flour contains glutenin and gliadin, proteins that can be manipulated in the presence of water to form gluten, a somewhat elastic and cohesive complex capable of providing much of the structure of baked products.
2. Other ingredients (e.g., eggs, sugar, salt, leavening agents, liquids, fats, or oils) may be added to contribute their unique functions in various baked products.
3. Ratios of ingredients and the techniques used in mixing batters and doughs, as well as baking conditions, all play roles in determining the characteristics of the end product.
4. Altitude influences the ratio of ingredients required to make successful baked products, particularly cakes.

**pour batter** Flour mixture with approximately equal amounts of flour and liquid (1:1 ratio); popovers and shortened cakes are examples.

**soft batter** Flour mixture with twice as much flour as liquid (2:1 ratio); muffins and drop cookies are examples.



**Figure 15.1**  
Popovers are made using a pour batter (ratio of 1 part flour to 1 part liquid). Courtesy of Plycon Press.



**Figure 15.2**  
Muffins are made using a soft batter (ratio of 2 parts flour to 1 part liquid). Courtesy of Plycon Press.

**soft dough** Flour mixture with approximately three times as much flour as liquid (3:1 ratio); biscuit and bread doughs are examples.

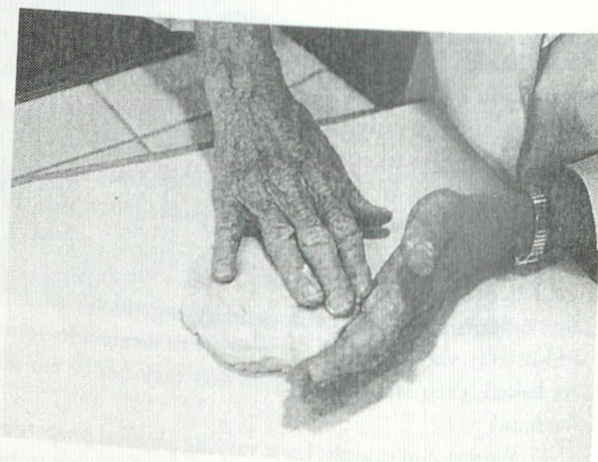
**stiff dough** Flour mixture with about eight times as much flour as liquid (8:1 ratio); pastry and pasta doughs are examples.

Doughs contain much less liquid in relation to flour, creating a mixture that can be handled if hands are lightly floured. **Soft doughs** (approximately three times as much flour as liquid) are somewhat resilient when they are kneaded (Figure 15.3). Yeast breads and baking powder biscuits are examples of baked products made from soft doughs. If about six to eight times as much flour as liquid is used, a **stiff dough** will result. Pastry dough is an example of a stiff dough (Figure 15.4) using six times as much flour as liquid, and pasta dough is even stiffer (eight times as much).

All baked products possess a structural network, a combination of protein and starch, responsible for holding the baked item together. Many studies of batters and doughs are directed toward the development and solidification of this network. Wheat, with its unique proteins, is the basis of high-quality batter and dough products. No other cereal or other type of food possesses the specific characteristics that can be developed when wheat flour is used in mixing and baking batters and doughs. The nature of wheat flour and its contributions to batters and doughs, as well as the roles of other ingredients of batters and doughs, are discussed in this chapter.



**Figure 15.3**  
Biscuits are made using a soft dough (ratio of 3 parts flour to 1 part liquid). Courtesy of Plycon Press.



**Figure 15.4**  
Pastry is made using a stiff dough (ratio of 6 parts flour to 1 part liquid). Courtesy of Plycon Press.

## WHEAT FLOUR

*Flour* is the name applied to any finely ground cereal grain, although many people use the term to mean specifically the product resulting from grinding wheat (Figure 15.5). The protein in wheat makes it possible to produce breads capable of withstanding the force involved in spreading butter or margarine on them. Protein also is responsible for the fact that cakes and pastries made with wheat flour can be cut and served without disintegrating.

Gluten, the key protein complex in wheat flour, is responsible for the elastic and cohesive nature of batters and doughs made with this type of flour. The starch in that same flour is of value in strengthening structure and absorbing the extra liquid during baking. However, the starch from any type of flour can perform these functions. It is the protein in wheat that is so distinctive.

### Milling

To obtain the flour used in making baked products, the wheat grains undergo a grinding and refining procedure, a process called **milling** (Figure 15.6). Milling begins with the grinding of whole wheat kernels after a very brief preliminary steam treatment (tempering), which facilitates separation of the outer layers and the germ from the endosperm (Chapter 10). Grinding shatters the endosperm and splits off the bran coating, although the bran tends to remain intact. At the same time, its fat content allows the germ to be pressed into flakes, and these separate readily from the endosperm.

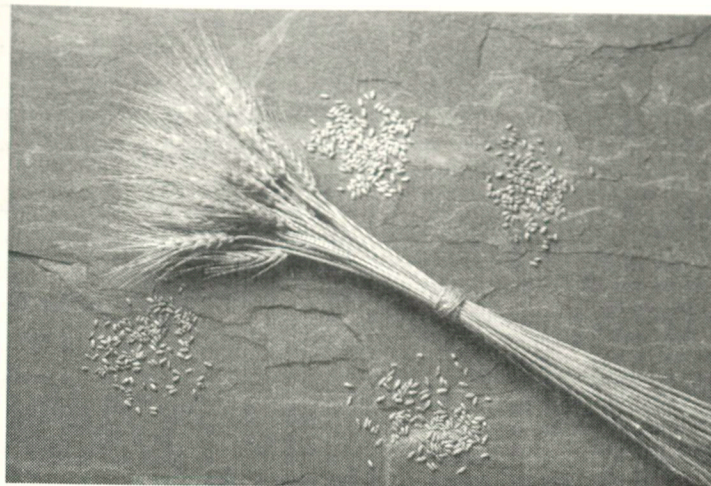
Separation of the various fractions of the kernel is done by using air currents. The differing weights of the various fractions cause them to be tossed with varying ease by the currents. The different fractions can be directed and collected in streams ranging from whole wheat flour to very refined for use in making particular flour products.

### Bleaching and Maturing

Freshly milled wheat flour tends to produce products with reduced volume and rather sticky doughs, characteristics that do not exist if a mature flour is used. Unfortunately, maturing or aging is costly because of the cost of the storage space and also because of prospective loss due to insects or rodents during prolonged storage. To overcome the performance objections and to shorten the storage times, the milling industry adds bleaching and maturing agents to the freshly milled flour. Additives approved for use include chlorine dioxide gas, acetone peroxides, and oxides of nitrogen. Soft wheat flours may be matured and bleached with chlorine gas and nitrosyl chloride. These bleaching agents lighten the pigments (xanthophyll and anthoxanthins) in the flour. The improved baking performance is attributed to a change in the chemical structure of the protein (see Science Note—Flour Proteins and Lipids on page 335).

### Enrichment

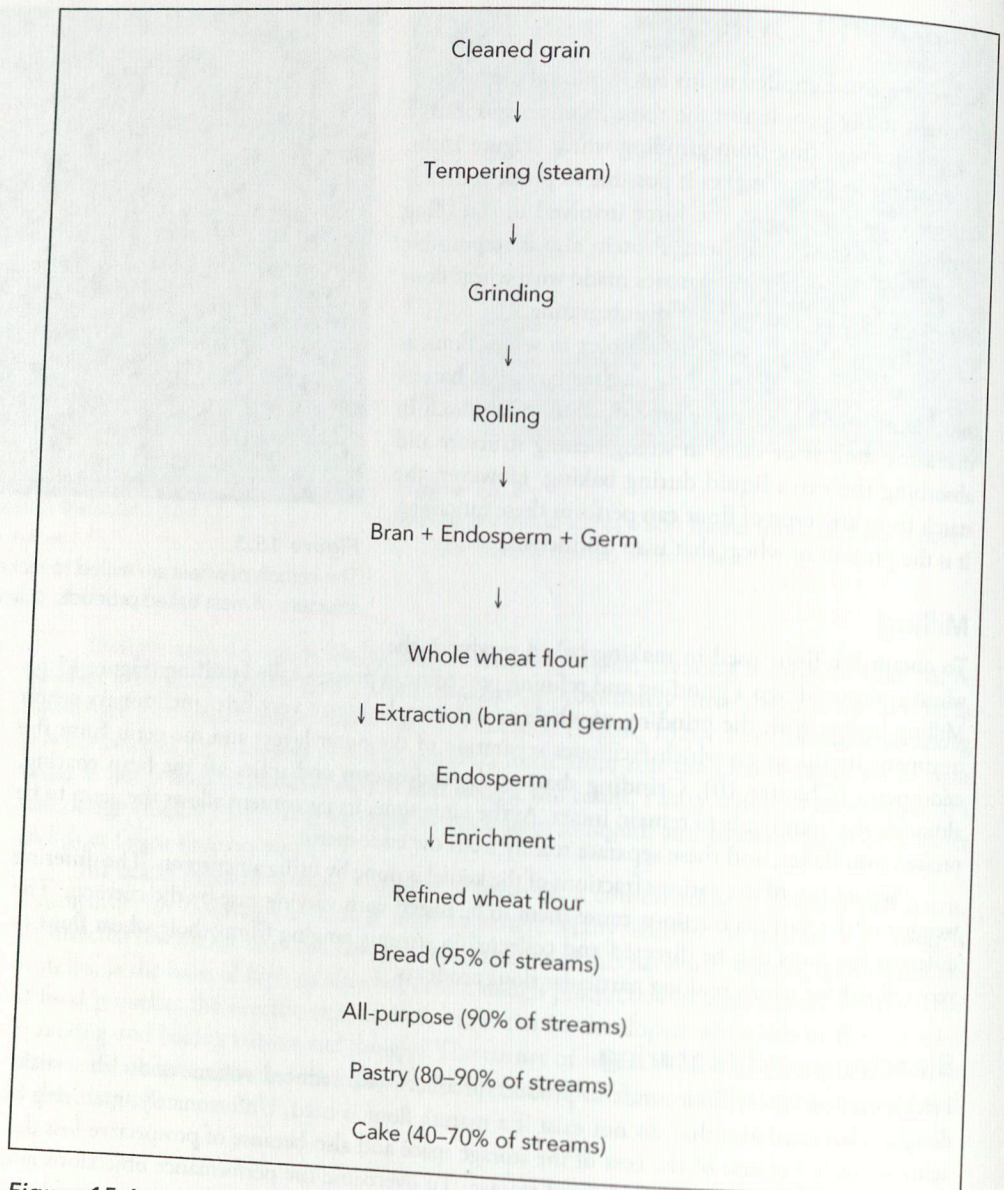
Since the milling of flour splits the vitamin- and mineral-rich bran and germ from the endosperm and removes these fractions in refined flours, much of the nutritive value of flour is lost. The advantage of milling is that the keeping quality of the refined flour is improved due to the removal of the germ and its fat (with its potential for becoming rancid). To compensate for the removal of important nutrients, a federal enrichment program requires the addition of 2.9 milligrams of thiamin, 1.8 milligrams of riboflavin, 24.0 milligrams of niacin, 0.7 milligrams of folic acid, and 20 milligrams of iron per pound of flour. Calcium is an optional additive, but if added, it is to be added at the rate of 960 milligrams per pound of flour.



**Figure 15.5**

The kernels of wheat are milled to make the flour that provides much of the structure of most baked products. Courtesy of Agricultural Research Service.

**milling** Grinding and separating of the desired fractions of the cereal kernel to produce flour.



**Figure 15.6**

Overview of the steps in milling wheat. Courtesy of Plycon Press.

Flour that has been enriched must bear a label indicating this, but there is no federal legislation requiring enrichment of refined flour. However, most states now have legislation mandating that all refined flour and bakery products made with refined flour must be enriched. Although the enriched flours are not enriched with all of the nutrients lost in milling and refining wheat, they are very wholesome and nourishing, and they do provide important sources of four B vitamins and iron.

Enriched refined flour produces lighter baked products with finer textures and volume than can be made using the whole-grain flour or blends of whole-grain flour with other cereal flours. However, the nutritive value of the whole-grain products is slightly higher, and their ranges of flavor, color, and texture are greater than in products made of enriched refined flour. The choice can be based on personal preference, for either flour represents an intelligent approach to good nutrition.

### Types of Flour

**Bread Flour** Bakers utilize bread flour when making breads because of the strong structure provided by the gluten it contains. The comparatively high protein in this hard wheat flour is ideal for developing the cohesive crumb quality needed in breads. Bread flour ordinarily is not available for home use.

<http://food.oregonstate.edu/learn/flourmixgen.html>

—Background information on flours.

<http://www.bettycrocker.com/products/gold-medal-flour>

—Extensive suggestions and information about baking.

<http://www.kingarthurflour.com/>

—Information on flours and baking.

<http://www.cookeryonline.com/Bread/index.html>

—Basic information on various flours.

<http://www.joyofbaking.com/RecipeIndex.html>

—Wide range of baking ideas and recipes.

<http://www.pillsburybaking.com/>

—Extensive suggestions and information about baking.

**All-Purpose Flour** **All-purpose flour** is made from hard wheat or a blend of hard and soft wheat. These types of wheat, commonly grown in the central part of the nation, usually result in a flour with a protein content of about 10.5 percent. The protein content is sufficient to make satisfactory breads, yet it is not so strong that cakes will be unpleasantly tough. Consequently, all-purpose flour can be used with reasonable success to make any type of baked product for families, which explains its other name—family flour.

All-purpose flour is available bleached and unbleached, to suit individual consumer preferences. The unbleached version is preferred by people who are concerned about additives in food and are willing to accept baked goods of somewhat reduced quality in preference to consuming additives. This clearly is a matter of individual choice, for there is no evidence of harm from the use of additives approved for bleaching flour.

**Cake Flour** The desired tenderness and fine texture in cakes are promoted by the use of **cake flour**. This type of flour, made from soft wheat, has a protein content of only about 7.5 percent. Not only is it significantly lower in protein than all-purpose flour, but the protein structure resulting from use of cake flour is more tender and finer than the comparable all-purpose product (Figure 15.7).

**Pastry Flour** **Pastry flour** is quite similar to cake flour in that it contains about 7.5 percent protein and also is made from soft wheat. However, it is not ground to as fine a particle size as is cake flour. This is the type of flour preferred by commercial bakers for making cookies and pastries, but it is not commonly available to home bakers.

**Whole Wheat Flour** As the name implies, the entire wheat grain is used in making **whole wheat flour**. The presence of the bran adds a slightly crunchy texture and a light brown color. Unfortunately, the presence of the germ limits the shelf life of whole wheat flour, because of the fat present in this portion of the grain. Products made with whole wheat flour are a bit more compact, lower in volume, and more chewy than those made with refined all-purpose flour.

**Self-Rising Flour** **Self-rising flour** is, in a sense, a partial mix for baking. It contains not only flour but also an acid salt (usually monocalcium phosphate), baking soda, and salt (sodium chloride), the amounts of these providing the equivalent of half a tablespoon of baking powder and half a teaspoon of salt per cup of self-rising flour.

Recipes stipulating self-rising flour have already been adjusted to compensate for these additions, but the salt and baking powder need to be omitted if using self-rising flour in recipes based on use of all-purpose flour. Similarly, self-rising flour is not well suited for use in yeast-leavened products. The wheat used in producing self-rising flour is a blend of hard and soft wheat to give a total protein content of about 9.3 percent, somewhat lower than the usual level in all-purpose flour. Self-rising flour is particularly popular in the South, where it is often preferred for making biscuits.

**Gluten Flour** The protein level in gluten flour is raised to about 41 percent by the addition of vital wheat gluten, a dry form. This gives a distinctly chewy texture to breads (usually marketed as gluten bread) made with this type of flour. From the perspective of nutrition, there is no need to use gluten flour, for the average American diet contains far more protein than is needed. However, it does add variety to the types of breads in the diet and clearly is an appropriate choice for those who like it.

**Other Flours** Rye flour is used in conjunction with wheat flour in making rye bread. Although rye flour has some capability in contributing to structure, the protein in rye is less cohesive and elastic than is that comprising the gluten in wheat.

**Triticale** is a comparatively new grain developed by crossbreeding wheat and rye. It carries some of the characteristics of both parent grains, but it cannot be used in place of wheat in achieving optimum quality in baked products. However, continuing research efforts exploring the utilization of triticale flour in baking may eventually make such products

**all-purpose flour** Flour from hard or hard and soft wheat blended; protein content of about 10.5 percent and suitable for making most baked products.

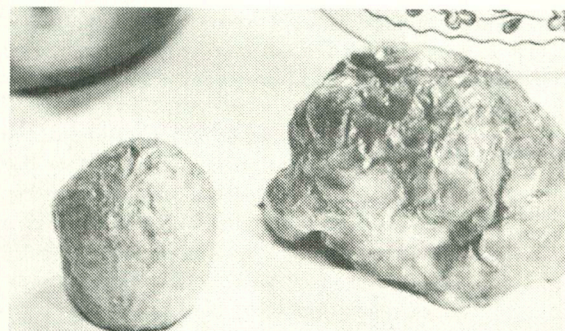
**cake flour** Fine-textured flour from soft wheat; contains about 7.5 percent protein.

**pastry flour** Moderately fine-textured soft wheat flour; about 7.5 percent protein.

**whole wheat flour** Flour containing the bran and germ, as well as the endosperm.

**self-rising flour** Flour containing the necessary amounts of baking powder and salt for preparing batters and doughs, making it necessary to eliminate these two ingredients from recipes if substituting self-rising flour.

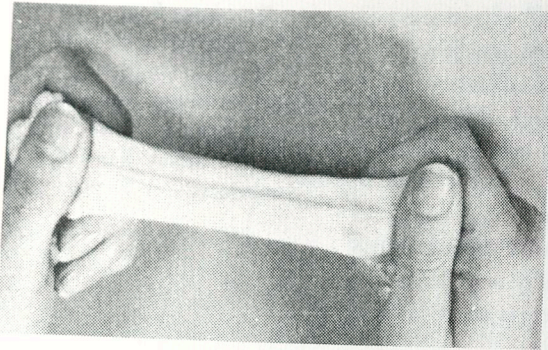
**triticale** Grain produced by crossing rye and wheat; its flour has a protein mixture with some potential for making good baked products.



**Figure 15.7**

Gluten ball from cake flour (left) and from all-purpose flour (right). The smaller content of protein in cake flour is evident when compared with the all-purpose flour product. The balls are essentially all protein, the starch having been removed by washing them under cold running water until no starch remains before baking.

Courtesy of Plycon Press.



**Figure 15.8**

Gluten, an elastic protein complex formed when wheat flour and liquid are manipulated together, is able to stretch during baking until the temperature becomes so hot that the protein denatures. Denatured gluten is responsible for much of the structure of baked products.

Courtesy of Plycon Press.

<http://www.bobsredmill.com/flours-meals/>

—Information on flours from various grains.

**gluten** Protein complex formed in batters and doughs when wheat flour is mixed with water or other aqueous liquids.

quite acceptable without the addition of wheat flours. The somewhat higher level of lysine in triticale, in comparison with wheat proteins, makes triticale of interest nutritionally because lysine is a limiting amino acid in wheat. Partial substitution of wheat flour with triticale flour in breads and other baked products can be done with good results.

## Use of Flour in Baked Products

**Gluten** When water and wheat flour are mixed together, a cohesive quality begins to develop in the dough or batter, leading to increased resistance to mixing and an elasticity. These characteristics are the result of an association between insoluble proteins in the flour to form a complex known collectively as **gluten** (Figure 15.8). Gluten can be stretched into fairly thin strands to form cell walls in batters and doughs during the early phase of baking and then to become rigid in the extended conformation as heat denatures the protein. In essence, this describes the significance of wheat gluten in providing the structure in baked products.

Development of the optimum gluten network is central to making batter and dough products of excellent quality. Too little gluten development is evidenced by a crumbly baked product that is difficult to serve. Too much gluten development results in a tough, chewy product with slightly reduced volume. The amount of mixing actually needed to develop gluten optimally depends upon the presence of other ingredients.

When the ratio of flour to liquid is high (1:1), as it is in popover batter, gluten is developed with difficulty. However, in muffins, which have a flour to liquid ratio of about 2:1, the batter is so sticky that the gluten strands tend to adhere to each other during mixing, causing them to develop readily. A similar situation is found in the somewhat more viscous 3:1 ratio of flour to liquid in biscuits, although the increased viscosity makes it possible to do somewhat more mixing in biscuits than in muffins before a tough product results.

The presence of added fat interferes with gluten development, making it necessary to increase the amount of mixing as the amount of fat in a recipe increases. The coating provided by the fat, coupled with the difficulty that water has in penetrating the fat coating to interact with

## CELIAC DISEASE AND GLUTEN-FREE

One of the food product areas emerging recently is gluten-free foods, which are targeted to meet the special dietary needs of people who have **celiac disease**, an autoimmune disease in which gluten in the diet damages villi lining the small intestine and interferes with absorption of nutrients. A diet free of gluten helps to prevent further damage to the intestinal wall. This may sound simple, but significant changes in the diet need to be made if this is to be achieved because gluten, the protein complex in wheat, is vital to making baked products with the desired texture.

Most breads, crackers, cookies, cakes, and pastries need to be eliminated because of their gluten content, and flours from rice, potato, quinoa, and a few other sources substituted. Additional possible alternatives to work with include corn, soy, tapioca, beans, sorghum, millet, buckwheat, teff, nuts, amaranth, and arrowroot. The problem is that the resulting products tend to have quite different textural properties compared with their counterparts containing wheat flour.

To make appropriate choices for a gluten-free diet, it is important to be aware that gluten is used in many food mixtures and products that are surprising. The only way to be sure is to read ingredient labels and watch for any of the following sources: durum wheat, semolina, graham, spelt, triticale, barley, rye, malt and malt vinegar (containing barley), breading, soup bases, imitation seafood and bacon, lunch meats, stuffing, beer, and even Communion wafers and vitamin and herbal supplements.

Some assistance in identifying safe food choices is becoming available as labeling requirements to protect against food allergens are implemented. However, the definition of gluten-free for labeling purposes is still not legally defined. Nevertheless, some products now are clearly identified as gluten-free, a situation that is of some help to shoppers needing these items. The food industry is working to meet the demand for safe foods for this significant part of the market, and many innovative products can be expected to appear in grocery stores in the coming years.

the gluten, is the apparent explanation for the increased need for mixing. Sugar also delays gluten development, seemingly because it competes for some of the moisture needed by the gluten.

The amount of liquid absorbed by gluten in batters and doughs varies according to the specific flour and its gluten-forming properties. Flours made with soft wheat absorb less water than do hard wheat flours. This difference in absorptive ability is very noticeable in preparing pastries, where the ratio of water to flour is particularly critical to the tenderness of the finished product. Typically, flours purchased in the South absorb less water than do flours purchased in the Midwest.

### SCIENCE NOTE

#### FLOUR PROTEINS AND LIPIDS

##### Soluble Proteins—Albumins and Globulins

The various proteins found in flour often are classified according to solubility. Two types of proteins—the albumins and globulins—are classified as soluble proteins. The comparatively small amount of these proteins (only about 15 percent) and the seemingly minimal significance of either of these globular proteins in relation to structure have caused the globulins and albumins in flour to gain little research attention.

##### Gluten

**Gliadin** The remaining 85 percent of the flour protein is said to be insoluble, although about half is soluble in alcohol. This protein, which is soluble in 70 percent alcohol, is called **gliadin**. When isolated from the other proteins, gliadin (molecular weight of 50,000) is a viscous liquid. The gliadin molecules, which are polypeptide chains in an apparently fairly spherical, compact shape, contribute to the sticky, flowing character of the gluten complex, partly because of their high glutamic acid content and consequent ability to form secondary bonds between molecules. People with celiac disease are sensitive to gliadin.

**Glutenin** **Glutenin** (molecular weight of 2–3 million) is considered to be the protein fraction responsible for the elastic quality of the gluten complex. Actually, glutenin is not a single protein, but consists of two and probably more fractions that have a somewhat fibrous character. Proline, which is abundant, limits the physical, spatial configurations the molecules may assume. Cystine, another amino acid occurring in glutenin, contributes disulfide bonds. In fact, the sulfhydryl groups and disulfide bonds, both of which are subject to change from oxidation and reduction, are involved in the elasticity of the gluten complex, a characteristic of considerable importance in achieving the desired volume.

**The Complex** For gliadin and glutenin to form an elastic and cohesive complex, manipulation is needed to bring these two fractions together in a complicated and intimate association. It is probable that the glutenin molecules associate to form a loose network of these elongated molecules, with the more compact gliadin molecules being trapped in this network in a somewhat random fashion. The fluid nature of the gliadin probably permits some slippage of the glutenin fibers over each other during mixing.

##### Lipids

Surprisingly, the elaborate combination of gliadin and glutenin to make gluten is not sufficient by itself to produce the familiar elastic and tenacious qualities seen in batters and doughs. The lipids naturally present in flour also are important, even though their quantity (less than 2 percent) may seem rather insignificant. The fats are present primarily as phospholipids and glycolipids. The glycolipids are primarily galactose combined with fat, giving molecules that can use hydrogen bonds and van der Waals forces effectively to bind with the proteins in the flour. It is hypothesized that the glycolipids in flour act almost like a sandwich filling between layers of the gluten complex.

Although the importance of lipids and of the two principal fractions of gluten (gliadin and glutenin) has been studied extensively, there still is much to be learned about the complex formation of the structure in baked products. Research is ongoing in this field of proteins and lipids and their interactions.

<http://www.nlm.nih.gov/medlineplus/celiacdisease.html>

—Information on celiac disease and diet.

<http://www.abcr.com/doc/Gluten%20Allergen%20Analysis.pdf>

—Summary of status of gluten-free labeling.

<http://www.fda.gov/Food/LabelingNutrition/FoodAllergensLabeling/GuidanceComplianceRegulatoryInformation/ucm111487.htm>

—FDA site for status of regulations about gluten-free labeling.

**gliadin** Sticky fraction of gluten.

**glutenin** Very large, elastic component of gluten.

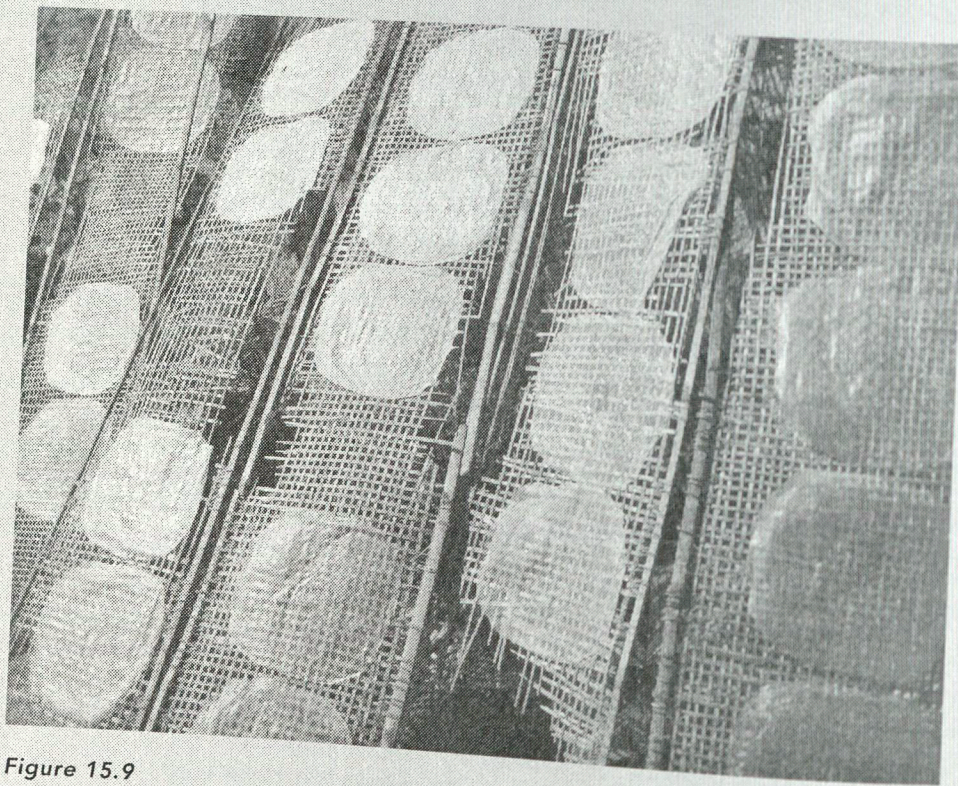
**Starch** During mixing, starch in flour plays a relatively minor role. It is not until the starch begins to undergo gelatinization in response to the heat in the oven that much water is absorbed into the granules. During baking, starch aggressively absorbs water in an attempt to gelatinize the granules. In very fluid batters, considerable swelling and gelatinization occur because there is sufficient liquid there for this physical change to progress smoothly.

Gelatinized starch contributes meaningfully to the strength of the cell walls in which the granules are embedded. In fact, moderately acceptable cakes can be made using pure starch as the primary structural ingredient when gluten-free baked goods are needed for special diets. This is in contrast to the high-quality cakes that can be prepared when flour, with both its protein and starch, is the principal structural agent.

### CULTURAL ACCENT RICE PAPER

Wheat flour is the flour of choice for most types of bread products, but rice provides the structure for the delicate wrappers used in making Vietnamese spring rolls. Rice flour lacks the structural qualities provided by the gluten complex in wheat flour, but the protein and starch in it can provide sufficient structure to allow cooks to form rice

paper wrappers. These look like very thin, semitransparent pancakes after they have been dried on long bamboo racks under the hot Vietnamese sun (Figure 15.9). Surprisingly, these rice papers are strong enough to be used as wrappers for spring rolls containing a variety of tempting fillings.



**Figure 15.9**

Rice paper drying on racks in the sun in Vietnam before being used to make spring rolls. Courtesy of Plycon Press.

## FUNCTIONS OF OTHER INGREDIENTS

### Eggs

Eggs, depending on the quantity used and the treatment prior to inclusion in the batter, may fulfill a variety of important functions in addition to adding to the nutritive value of the product. During the mixing of a batter or dough, eggs act as a liquid to help moisten dry ingredients and to assist in developing the gluten. The coagulation of egg proteins during baking adds to the stability of the structure of baked products, with the actual importance of this added strength being dependent on the amount of egg used. In popovers and angel food cakes, for example, the amount of protein provided by the eggs is an important adjunct to the structure provided by the flour. Additionally, eggs contribute flavor, and, when the yolks are used, color also is enhanced.

Beaten eggs add to the leavening of baked products because of the air they hold trapped within the foam. Egg white foams are particularly important in aiding with leavening. However, the egg yolk foam used in sponge cakes is a good example of the fact that yolks can also be significant sources of air.

The emulsifying ability of egg yolks is an important factor in producing smooth cake batters. Another example of the use of egg yolks as emulsifying agents is in the preparation of cream puffs, for they contain a very large proportion of fat, which would separate from the flour and liquid were it not for the binding ability of the egg yolks, with their content of lecithin, a noted emulsifying agent.

### Sugar

The obvious function of sugar in baked products is to provide a sweet taste. If light or dark brown sugar is used in place of refined sugar, additional flavors are added. Honey is yet another source of sweetness and accompanying flavor variations. Sugar substitutes afford an alternative means of sweetening baked products. However, these variations in the form of sweetening, when substituted in batters and doughs for refined sugar, quickly reveal that sugar does far more than merely sweeten baked products.

One of the important contributions of sugar is to aid in the browning of the crust of baking products. Although the sucrose (refined sugar) itself does not participate in the Maillard reaction, glucose and fructose liberated by hydrolysis from the original sucrose can react with protein to cause surface browning. In fact, when honey or fructose is substituted for refined sugar in batters and doughs, the Maillard reaction is much more intense because of the abundance of reducing sugar available from either of these sources.

Tenderness and volume of baked products are important characteristics influenced by the amount of sugar in relation to other ingredients in batters and doughs. The strongly hygroscopic (water-attracting) nature of sugar introduces a strong competition with flour for the liquid, which means that sugar will decrease the amount of liquid actually available to the developing gluten complex. This change means that additional mixing is needed to develop the gluten satisfactorily in products containing sugar.

The amount of mixing needed increases directly with the increase in the quantity of sugar. This can be illustrated by comparing the preparation of muffins and shortened cakes. Muffins have a very small amount of sugar added, and a minimal amount of mixing is required to develop the gluten appropriately. On the other hand, shortened cakes have a comparatively large amount of sugar (and other interfering ingredients, too), necessitating a considerable amount of manipulation to develop the desired gluten network. Actually, sugar is a helpful ingredient during mixing because it allows sufficient time for adequate blending of the ingredients before the gluten is developed too much.

Sugar also has a tenderizing effect, due to two actions. As just noted, gluten development is delayed by sugar, and this delay helps to keep gluten from becoming so developed that it is tough and chewy. The second action to help tenderize products by adding sugar is involved in the baking period. An increase in the amount of sugar in a recipe results in a somewhat higher coagulation temperature of the protein present.

If a baking flour mixture has to be heated to an elevated temperature before the gluten denatures and sets the structure, the elastic nature of the gluten will be maintained for a longer time than if no sugar is present. During this extended period when the gluten remains elastic, the pressure of the hot gases within the cells keeps stretching the cell walls thinner and thinner. Thin cell walls are more tender than thick ones. In short, the sugar causes a higher coagulation

temperature and longer period of time for stretching the gluten into thin cell walls before denaturation occurs; this is the second reason for regarding sugar as a tenderizing ingredient.

The increased temperature of denaturation of the gluten when sugar is increased also explains the way in which sugar influences volume. Up to a certain critical point, increasing sugar will increase volume because of the extended period of stretching cell walls. However, if cell walls get stretched too thin before the gluten denatures, the cells will explode when the gluten strands break from the pressure generated by the hot gases. This situation is analogous to blowing up a balloon until it is stretched so thin that the material simply cannot stretch enough to accommodate the pressure of the enclosed air and it pops. When the cells in baking products reach the point of exploding, the product falls and remains extremely compact no matter how much longer it is baked.

Sugar substitutes do not have effects comparable to sugar on the tenderness and volume of baked products because they have little influence on the development and coagulation temperature of the gluten. Even the use of sugars other than sucrose will give somewhat different results in tenderness and volume.

### Salt

Salt is used to enhance flavors in baked products. Its other function is to regulate the growth of yeast in yeast doughs, where it serves to counterbalance the stimulating effect of sugar and to help tighten the gluten, both of which aid in avoiding a coarse texture.

### Leavening Agents

Leavening agents, as discussed in Chapter 14, are necessary to increase the volume and promote development of the desired texture in baked products. They need to be included in amounts adequate to achieve the desired volume without imparting an undesirable flavor or aftertaste, usually 1–2 teaspoons of baking powder per cup of flour for most baked products.

### Liquids

Milk is the liquid used most commonly in batters and doughs, though water, sour milk, sour cream, or fruit juices sometimes are used. Liquid aids in the development of the gluten. Without liquid to help hydrate the mixture, gluten does not develop. Liquid also is needed to gelatinize starch during the baking period; gelatinized starch adds rigidity and strength to cell walls. Fruit juices and the other liquids with distinctive flavors add to the flavor of the baked product, but they may affect the denaturation of protein and the gelatinization of starch.

Leavening action is provided by liquids when they are converted to steam during baking. They also serve as a solvent to activate the reaction of baking powder to produce carbon dioxide. Unless baking powder is dissolved, the reaction between the soda and acid salt will not occur. Similarly, baking soda must be dissolved if it is being used in conjunction with an acid ingredient. For example, the liquid in sour milk dissolves the soda, and the acid in the milk then reacts with the soda to generate carbon dioxide for leavening.

### Fats and Oils

An important function of fats and oils is to tenderize baked products by impeding gluten development. The coating of fat that develops on gluten strands tends to block water from the flour proteins needing the liquid for gluten development. This coating of fat also has a lubricating effect.

The texture of various baked products reflects the type of fat used, particularly in recipes where the fat content is comparatively high. For instance, pastry made with oil tends to have a granular texture in contrast to the flaky, layered texture of a pastry made with a firm fat, such as shortening. Fats also promote a soft crumb in breads and cakes.

Fats contribute to the flavor of baked goods, especially when a flavorful one (butter or margarine) is used. Even when the fat itself has little apparent flavor, there is a richness of flavor that is promoted by the presence of the fat. Yellow margarine, butter, and other colored fats may add to the creamy color of breads, cakes, and other items. This color often is perceived as indicating a particularly rich and flavorful product.

The specific contributions made by a fat are dependent in part upon the type being used (Chapter 8). Selection of the appropriate fat for making a specific batter or dough can result in a

product with optimum characteristics. Since the physical properties and composition vary from one type of fat to another, it is necessary to modify recipes when substitutions of fat are made.

## MIXING TECHNIQUES

Individual technique in preparing batters and doughs can have a very significant effect on the final volume, texture, and tenderness of baked products. Certain key words are used in recipe instructions to indicate the operations to be used during preparation. Each of the following terms has a specific meaning in relation to preparing batters and doughs. These need to be understood and then practiced until quality products are prepared each time.

**Creaming** is the creation of a heavy, air-in-fat foam by agitating solid fat and sugar together until the mixture is somewhat light and fluffy. This may be done with the aid of an electric mixer or by mixing fairly vigorously with a wooden spoon or paddle. Creaming should be discontinued if the mixture begins to lose volume and becomes soft.

**Beating** is rapid agitation of a mixture of foods with the aid of an electric mixer or a wooden spoon. This action is more vigorous than creaming and is applied on a wide range of ingredients. Usually the purposes are to beat in air and to develop gluten.

**Stirring** is gentle mixing of ingredients to blend them thoroughly. This technique is used when trapping of air is not necessary and when excessive gluten development needs to be avoided.

**Folding** is a gentle motion designed to bring ingredients up from the bottom of the mixing bowl and spread them across the upper portion of a foam or batter with minimum disruption. This process is repeated, with every fifth stroke coming up through the middle to facilitate uniform blending, until the entire mixture is homogeneous. A rubber spatula is particularly well suited for folding, because it scrapes the ingredients up from the bottom efficiently. Other utensils suitable for folding include a narrow metal spatula or a wire whip or whisk. The important action in folding is to blend ingredients thoroughly with a minimum development of gluten or loss of air from the foam.

**Cutting in** is the technique used to cut solid fats into small particles in the preparation of pastries and biscuits. A pastry blender (see Figure 4.8) is designed specifically for doing this task efficiently, but two table knives can be used in a crosscutting motion to accomplish the desired result. A light, tossing motion with the pastry blender is important in avoiding packing the fat into a solid mass while the cutting in is being done.

**Kneading** is the mixing together of ingredients with the hands or a dough hook on a mixer. Techniques for kneading vary, depending upon the amount of gluten needing to be developed. In yeast breads, considerable gluten needs to be developed, so the kneading technique involves a folding over the dough and then a vigorous push with the heel of both hands simultaneously. The dough is rotated a quarter of a turn, and the process is repeated in a

**creaming** Mixing fat and sugar together vigorously to create an air-in-fat foam.

**beating** Very vigorous agitation with a wooden spoon or on a mixer at high speed to trap air and/or to develop gluten.

**stirring** Gentle blending of ingredients when trapping of air and development of gluten are not needed.

**folding** Very gentle manipulation with a wire whisk, narrow metal spatula or rubber spatula to bring ingredients up from the bottom and spread them over the upper surface to aid in blending them uniformly.

**cutting in** Process of cutting solid fat into small pieces using a pastry blender or two table knives.

**kneading** Folding over a ball of dough and pressing it with either the fingertips or the heels of both hands, depending on the amount of gluten needing to be developed and the ratio of ingredients.

### INGREDIENT HIGHLIGHT COOKING SPRAYS

Cooking sprays have been available for more than half a century, and they have found a niche in many kitchens because of their convenience, versatility, and long shelf life. Because they can be sprayed directly onto baking pans and sheets, bakers can avoid the messy task of greasing them to prevent sticking. This treatment makes it practical to use baking equipment that does not have a nonstick coating, thus avoiding any possible effects from eating food baked on coated surfaces.

Although any cooking spray can be used successfully for coating baking pans, special baking sprays containing a small amount of flour have been formulated specifically for this task. If people with celiac disease will be eating the products,

a regular cooking spray should be used instead of the baking spray. Also, butter-flavored cooking spray will have a small amount of lactose, which makes this a type of cooking spray to be avoided by those who have severe lactose intolerance.

People who bake and prepare other foods at home may wish to keep a container of at least the general-purpose cooking spray handy in a cupboard for quick use whenever preparations require it. The can has a shelf life of two years, which means that it will be safe to use for a long time, a fact that is important in view of the small amount used for each application. For optimal results, the can needs to be shaken vigorously to disperse the components uniformly before spraying.

rhythmic pattern until the gluten is developed to the point where blisters can be seen under the surface of the dough, but the dough itself has a smooth surface.

Since gluten develops very readily in preparing biscuit dough, the folded dough is pushed gently with just the fingertips of both hands, after which it is rotated a quarter of a turn, and the process is repeated. Only a brief period with this gentle kneading stroke is used for making biscuits to avoid causing them to become tough. Kneading not only mixes ingredients; it also develops the necessary gluten network and contributes to the desired flaky quality of biscuits. In contrast, so much kneading is done when making yeast bread doughs that the layers of the folded dough tend to merge together into a continuous gluten network, and layering or flakiness is not present.

## BAKING

Preparation of pans for baking varies with the product and with the container selected. Breads being baked in pans with sides can be removed easily if the sides and bottom of the pans are sprayed with nonstick cooking spray or greased lightly (unless the pan has a coating). If the bottom of the cake pan is lined with a layer of wax paper, sprayed with nonstick cooking spray, or greased, layer cakes can be removed easily. The sides are not greased, which helps the cake cling to the sides and pull upward during baking.

Foam cakes (angel food, sponge, and chiffon) can be removed easily when baked in ungreased tube pans of two-part construction. Nonstick coatings on tube pans are not recommended when foam cakes are being prepared, because the cakes are likely to fall out when the pan is inverted to maintain the cake at maximum volume during cooling. Usually, cookies are baked on nonstick cookie sheets or jelly roll pans or simply on ungreased sheets. A spatula is used to remove cookies from the baking sheet when they come out of the oven because they tend to break if they cool before being loosened. Ungreased cookie sheets save the problem of burning and polymerizing fat in all of the areas where the bare pan is exposed between the cookies.

The rack position should be checked and shifted if necessary before the oven is turned on. When baking in a preheated oven, baking pans should be placed in the center rack position, with sufficient space between pans and between the pans and the oven edges to permit good air circulation and achieve relatively uniform browning. Pans should not be placed directly underneath one another—the top pan will not bake adequately on the bottom, and the bottom pan will be too done on the bottom and very pale on the top.

Preheating allows baking to begin immediately at the desired temperature, but this practice wastes energy. Yeast breads should be baked in a preheated oven when volume has doubled, or else they should be started in a cold oven before they have doubled in volume. Too much oven spring occurs, and a coarse texture results if a cold start is used on rolls that already have doubled.

If starting cakes, quick breads, or other baked products in a cold oven, the oven rack should be positioned just above the center. This added distance from the heating element at the bottom will eliminate excessive browning (or possibly burning) while the oven is being heated to the appropriate temperature. When baking from a cold start, more time is necessary than is indicated in the recipe to reach the desired end point because of the low temperature during the early phase. Foam cakes have the potential to lose gas from the foams and for the heavier ingredients to begin to drain toward the bottom to form a layer if baking is delayed; starting in a cold oven adds to this problem.

The structure of baked goods is most delicate immediately prior to denaturation of gluten, for this is when the expanding gases are still stretching the cells. Until denaturation occurs, gluten is extensible and requires that gases in the product maintain pressure. However, denaturation halts stretching and sets the structure. At that point, baked products can be removed from the oven, because the cell walls are strong enough to maintain the structure and no longer need to be supported by hot gases.

Tests for doneness need to be made for baked products to be sure that the structure has been set throughout. However, testing should not be done until the product should be done; this avoids letting cold air into the oven at the most critical stage of baking. Tests in the center give information about the exact state of affairs at the coolest point. Shortened cakes and loaves of quick breads are tested by inserting a toothpick in the center and checking to be sure that no batter is clinging to it when it is withdrawn. Foam cakes are done when they spring back after being touched lightly on the surface. Yeast breads, pastries, cookies,

and many quick breads are checked on the basis of elapsed time and appropriate browning.

## TREATMENT FOLLOWING BAKING

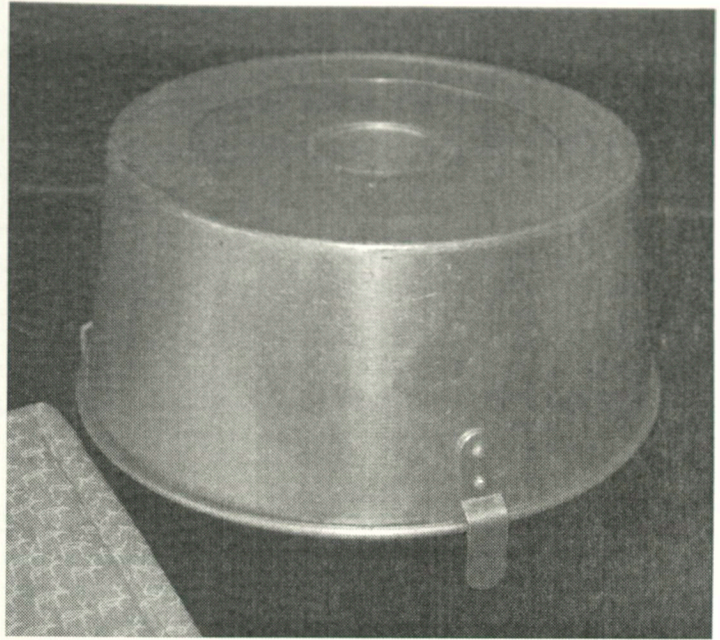
The strength of the structure immediately after baking determines the way in which a specific product will be cooled. Drop cookies, for example, usually are strong enough to be lifted off the baking sheet gently with a spatula when they come from the oven, whereas they will tend to break if allowed to cool on the sheet before they are loosened. Cakes, with the exception of foam cakes, are placed upright on a rack to permit air to circulate under the pan and hasten the cooling. Layers can be cut loose from the edges of the pan, covered with an inverted plate, and then turned over abruptly to unmold them onto the plate while the pan feels warm, but not hot, to the hand.

Foam cakes have weak structures when they first come from the oven, and the weight of the cake pushing down on itself in the pan will cause loss of volume while the cake is cooling. This problem is avoided by inverting the tube pan as soon as the cake is taken from the oven and letting the cake hang suspended until the pan is cool (Figure 15.10). This stretches out the cells during the cooling period, resulting in maximum volume. Once foam cakes have cooled, they can be removed from the tube pans by cutting them loose around the outer edge and the tube, removing the tube with the cake, and then cutting the cake loose from the bottom of the pan before inverting the tube and cake onto a suitable plate.

Quick breads and yeast breads are quite strong even when first removed from the oven. Therefore, there is no reason to delay taking them from their pans (Figure 15.11). Unless they are being served at once, breads should be transferred from pans onto cooling racks immediately. Otherwise, the crusts will become soggy from condensing steam.

## ADJUSTMENTS FOR ALTITUDE

The decreased atmospheric pressure at elevations of 3,000 feet or more causes detectable changes in the quality of baked products unless some modifications in the formula are made. The recommended changes are based on the fact that expansion occurs more readily at high altitudes than at sea level, where atmospheric pressure is greater. This creates greater resistance to expansion at low elevations than in the mountains. To avoid having cell walls rupture, recipes are modified in the mountains to strengthen cell walls and decrease pressure within the cells (Chapter 17, Science Note—High-Altitude Baking).



**Figure 15.10**

Foam cakes are inverted to cool as soon as they are removed from the oven so that the cells will be stretched by gravity to help retain maximum volume until cool enough to be removed from the pan. Courtesy of Plycon Press.



**Figure 15.11**

Breads have a strong structure even when first taken from the oven. To avoid soggy crusts, breads should be removed immediately from baking pans and cooled on a rack. Courtesy of Plycon Press.

### INDUSTRY INSIGHT

#### ANTISTALING ENZYME

Staling of baked products is a problem in commercially prepared breads, cakes, cookies, and pies, for this quality limits their shelf life. Amylose, the linear starch fraction, begins to undergo retrogradation as the product cools. Eventually, amylopectin (the branched fraction of starch) also begins to retrograde, resulting in a somewhat rapid, partially crystalline texture.

Boyle and Hebeda (1990) reported that a rather heat-resistant enzyme, Multifresh<sup>®</sup>, is able to prevent

rapid staling. The enzyme, an  $\alpha$ -amylase produced by *Aspergillus niger*, hydrolyzes some of the branches of the amylopectin starch molecules. These less-branched amylopectin residues are not able to bond easily with other amylopectin molecules, and staling is delayed. Multifresh is approved by the Food and Drug Administration for use in bakery products.

## SUMMARY

Wheat flour is the basic ingredient in most baked products because of its unique combination of insoluble proteins. When water is added and the mixture is manipulated, these proteins can be worked into a cohesive, elastic complex called gluten. To obtain wheat flour suitable for the consumer market, the wheat grain is milled, bleached, matured, and enriched (if the bran and germ have been removed to make a refined flour).

Bread flour is a high-protein flour available primarily to commercial bakers. All-purpose flour, made from hard wheat or a blend of hard and soft wheat to give a protein content of about 10.5 percent, is well suited to the preparation of breads, cookies, pastries, and even some cakes. Cake flour has a protein content of only about 7.5 percent; the rather tender protein from this soft wheat flour is well suited to making cakes. Pastry flour is similar, but a bit coarser than cake flour. Other flours on the market include whole wheat flour, self-rising flour (contains an acid salt, soda, and salt), gluten flour, and flours from other cereals (rye and triticale, for example).

Wheat flour is able to provide the basic structure of baked products because of the protein strands that are developed during the mixing of batters and doughs. Gluten (the protein complex) is a combination of gliadin, a sticky and viscous protein, and glutenin. Glutenin contributes the necessary elasticity to the unbaked protein complex.

Lipids in flour are also involved in the formation of the structure during mixing and baking. Sugar and fat delay the development of gluten; the ratio of liquid to flour also influences how readily gluten develops during mixing. Gluten needs to be developed sufficiently to hold the baked product together, but not so much that it becomes tough. When properly developed, gluten will be able to stretch into appropriately thin cell walls during baking, yielding a good volume and a tender product.

Starch is also an important structural component of flour. During the baking period, starch absorbs water as gelatinization occurs. The gelatinized starch granules are

embedded in the gluten matrix to help add rigidity to the structure after baking.

Eggs add another element to the structure of many baked products. They also contribute air for leavening when they are beaten into a foam. Other contributions are flavor, color, and emulsifying ability.

The pleasing golden-brown crust on baked products is due in large measure to the Maillard reaction, a combination of sugar with protein. Of course, sugar contributes a sweet taste, too. Sugar promotes volume and tenderness by modifying the rate of gluten development during mixing and by raising the coagulation temperature of gluten during baking. Sugar substitutes do not have these effects.

Salt is primarily a flavoring substance, although it does serve to retard carbon dioxide production by yeast. Leavening agents are valued primarily because of their influence on volume. Between 1 and 2 teaspoons of baking powder per cup of flour usually are sufficient to leaven products appropriately without leaving an objectionable aftertaste.

Liquids are needed to develop gluten and to gelatinize starch. They aid leavening by dissolving baking powder and baking soda, as well as providing steam during baking. Most liquids also contribute some flavor.

Tenderness and fullness of flavor are two characteristics promoted by the use of fats or oils. By interfering somewhat with gluten development, they aid in producing a tender product. The form of fat used and the way in which it is incorporated often influence the texture. Flavor and color may also be a reflection of the type of fat used.

For production of high-quality baked products, it is important to know and to practice the basic mixing techniques (creaming, beating, stirring, folding, cutting in, and kneading) and to follow appropriate baking guidelines. Optimal results are obtained when the correct pans are prepared appropriately and when the panned product is arranged in the correct position in the oven and baked until the correct end point is reached.

## STUDY QUESTIONS

1. What are the differences between all-purpose flour, cake flour, and whole wheat flour? What are the effects of using each of these types of flour in making batter and dough products?
2. What factors influence the rate of gluten development in batters and doughs?
3. What adjustments are needed if self-rising flour is to be substituted for all-purpose flour in a recipe?
4. Why is the starch content of flour important in baked products?
5. In baked products, what are the functions of (a) eggs, (b) sugar, (c) butter, (d) shortening, and (e) liquids?

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