Chapter 5

Wheat Flour

CHAPTER OBJECTIVES

1. Describe the makeup of the wheat kernel and its endosperm.
2. Classify common flours and other wheat products used in bakeshops and describe their characteristics and uses.
3. Describe common flour additives and treatments.
4. List the functions of flour and relate these functions to makeup.
5. Describe how to best store and handle flour.

Introduction

Wheat is a cereal grain. Other cereal grains include corn (maize), oats, rice, and rye. Widespread consumption of cereal grains began in the Middle East about 10,000 years ago, when agriculture first began. It was then that wheat was first planted and cultivated.

Today, thousands of varieties of wheat are grown throughout the world, most requiring fertile soil and a temperate climate. Several locations in North America have ideal conditions for growing high-quality wheat, including the midwestern United States and the southern prairie region of Canada. Other major wheat-growing countries include China, India, France, and Russia.

Wheat is more popular than any other cereal grain for use in baked goods. Its popularity stems from the gluten that forms when flour is mixed with water. Without gluten, raised bread is hard to imagine. Wheat is also preferred because of its mild, nutty flavor. Both factors, no doubt, account for wheat being the most widely grown cereal grain in the world.

Wheat Kernel

Wheat kernels are the seeds of the wheat plant, and they are the part of the plant that is milled into flour. Since cereal grains are in the grass family, wheat kernels can be thought of as a type of grass seed. In fact, when a field of wheat starts to grow, it looks like lawn grass.

Wheat kernels have three main parts: the endosperm, the germ, and the bran (Figure 5.1). While whole wheat flour contains all three parts of the kernel, white flour is milled from the endosperm. Whole wheat flour is considered a *whole grain product* because it contains the entire wheat kernel.

The *endosperm* makes up the bulk of the kernel. It is the whitest part, partly because it contains mostly starch—typically 70–75 percent starch. The starch is embedded in chunks of protein. Two important proteins in the endosperm of wheat kernels are the gluten-forming proteins, *glutenin* and *gliadin*. When flour is mixed with water, glutenin and gliadin form strands of gluten, important in the structure of baked goods. In fact, wheat is the only common cereal grain that contains sufficient glutenin and gliadin for the formation of good-quality gluten for bread making. Gluten and its unique properties are described in more detail in Chapter 7.

The *germ* is the embryo of the wheat plant. Given the right conditions, the germ sprouts—germinates—and grows into a new plant (Figure 5.2). Wheat germ is high in protein, fat, B vitamins, vitamin E, and minerals. These nutrients are important to the germ as it sprouts. While germ protein does not form gluten, from a nutritional standpoint it is of a high quality.

The *bran* is the protective outer covering of the wheat kernel. It is usually darker in color than the endosperm, although white wheat, which has a light bran

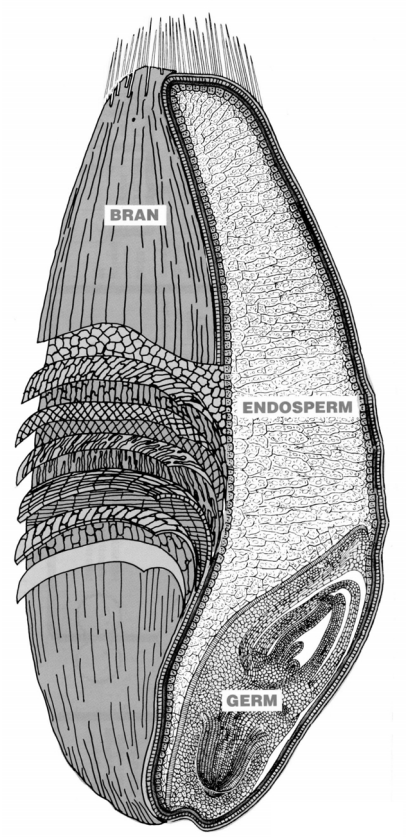

Figure 5.1 Longitudinal section of grain of wheat
Courtesy of the Wheat Foods Council

Figure 5.2 Germinating wheat kernel
Courtesy of Stephen Symons, Canadian Grain Commission

color, is also available. In either case, the bran is relatively high in dietary fiber. In fact, the bran is about 42 percent dietary fiber. It also contains a good amount of protein, fat, B vitamins, and minerals. As with wheat germ, the bran proteins do not form gluten; in fact, you will see later in this chapter that wheat germ and bran actually interfere with gluten development.

Makeup of Flour

White flour—the ground endosperm—contains mostly starch, yet other components naturally present in white flour affect its properties. The main components in white flour are listed below, with approximate percentages provided in parentheses. Of these, the two key components are starch and protein. Figure 5.3 illustrates the major components in flour and the relative amounts of each in typical bread flour.

Starch makes up the bulk of flour (68–76 percent). Even bread flour, considered "low" in starch, contains more starch than all other components combined. Starch is present in flour as small grains or *granules*. Some starch granules are damaged during the milling process or when flour is stored under damp conditions. When this happens, a very small amount of starch is broken down by amylase into sugars that are readily fermented by yeast. The amount of *sugars* naturally present in flour (less than 0.5 percent) is rarely high enough for proper yeast fermentation, which is why most yeast dough formulas include at least some sugar or a source of amylase.

Chunks of *protein* (6–18 percent) act as the cement that holds starch granules in place in the endosperm. Together, glutenin and gliadin, the gluten-forming proteins, make up about 80 percent of the proteins in the endosperm. Other proteins in white flour include enzymes, such as amylase, protease, and lipase.

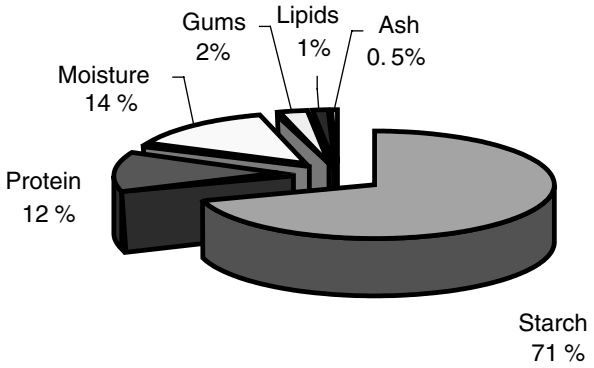

Figure 5.3 The makeup of bread flour

Moisture in flour typically ranges from 11–14 percent. When moisture content rises above 14 percent, flour is susceptible to fungus and mold growth, flavor changes, enzyme activity, and insect infestation. For these reasons, flour must be stored properly, covered and in a cool, dry place.

Other carbohydrates in flour besides starch include *gums* (2–3 percent), specifically *pentosans*. It is easy to overlook the importance of pentosan gums in white flour because they are present at relatively low levels. But they have at least one important function in flour. Because they typically absorb 10–15 times their weight in water, a small amount of pentosan gums makes a large contribution to the water absorption value of flour and to the consistency of batters and doughs. The small amounts present in wheat flour also appear to interact with gluten, improving its strength and structure. Pentosan gums are also a source of soluble dietary fiber.

Although only a small amount of *lipids* (1–1.5 percent)—oil and emulsifiers—are present in white flour, they are necessary for proper gluten development. Yet, because of its nature, wheat oil oxidizes easily and turns rancid, limiting the shelf life of flour. While not dangerous or unsafe, stale flour has a distinct cardboard flavor that is best avoided by storing flour properly and using it promptly.

Ash is composed of inorganic matter—mineral salts—naturally present in wheat kernels. It includes iron, copper, potassium, sodium, and zinc. Besides providing needed minerals to the diet, ash increases yeast fermentation by providing minerals to yeast. Ash has a gray color that carries over to the flour. If properly milled, however, white flour is relatively low in ash (less than 0.6 percent), because ash is concentrated in the bran layer, which is separated from the endosperm when white flour is milled. Ash is measured in flour and grain samples by burning the samples at very high temperatures—over 1000°F (538°C)—and weighing the remains.

Carotenoid pigments are present in white flour in extremely low amounts (1–4 parts per million). They provide the creamy, off-white color to unbleached flour. The carotenoid pigments in white flour are in the same family as beta-carotene, the orange pigment in carrots.

Classifying Wheat

Bakers generally classify wheat by the hardness of the kernel, that is, by whether the kernel is *hard* or *soft*. Hard wheat kernels are high in protein; soft wheat kernels are low in protein. Hard wheat kernels feel harder than soft ones because protein in these kernels forms large, hard chunks. Hard wheat kernels typically are higher in carotenoids than soft wheat kernels are.

Flours milled from hard wheat kernels are creamy or creamy white in color. They feel slightly gritty and granular, because the hardness of the kernel makes them difficult to mill. This coarseness means that hard wheat flours do not pack easily when squeezed and are good for dusting the bench. Typically, hard wheat

Additional Ways of Classifying Wheat

While the most common way to classify wheat is to consider the hardness of the kernel, there are other ways. Wheat can be classified by its botanical species, by the time of year it is planted or grown, or by the color of the kernel. In fact, the six major classes of wheat are described as hard red winter, soft red winter, hard red spring, hard white, soft white, and durum. Except for durum wheat, most wheats milled into flour in North America are varieties of so-called common wheat (Triticum aestivum).

Understand that the quality of flour within any of the above categories can vary greatly. In particular, geographic, climatic, and soil variations affect the composition and quality of wheat. That is why millers typically blend flours from different regions to provide consistent product year after year.

flours form high-quality gluten, meaning gluten that stretches nicely and forms strong, cohesive films. Because they form strong gluten, hard wheat flours are considered *strong flours.* Strong flours usually have a high water-absorption value and require a longer mixing time to fully develop, but they are tolerant of overmixing. Strong flours are typically used in yeast-raised products, like breads, rolls, croissants, and Danish.

Flours milled from soft wheat kernels are whiter in color and finer to the touch than hard wheat flours. They tend to pack when squeezed and do not flow or dust the bench easily. Soft wheat flours typically form weak gluten that tears easily, and are sometimes called *weak flours*. Weak flour is not necessarily less desirable than strong flour. It produces more tender products, and this is desirable for many cakes, cookies, and pastries.

Particle Size

Wheat and other cereal grains can be milled into many different forms, from very fine flour to cracked or whole kernels. Small, fine particles absorb water quickly. Large particles, such as whole and cracked kernels and coarse meals and flakes, often require soaking or gentle heating in liquid before use, to allow for proper water absorption and softening.

FLOURS

Flours by definition are grains milled to a relatively fine granulation size. Not all flours have the same granulation, however. For example, soft wheat flours are typ-

ically ground finer than hard wheat flours because the softness of their kernels allows it.

GRANULAR PRODUCTS

Granular products are coarser than flour. Like flours, they can be whole grain, if milled from the whole kernel, or not, if milled from the endosperm. Examples of granular wheat products include farina, ground from the endosperm of hard red wheat. Cream of Wheat is an example of a brand of farina. Durum semolina is coarsely ground from the endosperm of durum wheat. *Semolina* is from the Italian for *farina.*

Meals and grits are available in a variety of sizes, from coarse to fine, and each provides a slightly different texture to baked goods.

CRACKED KERNELS

Cracked kernels are whole kernels that have been cracked or cut, not ground like flour. Examples of cracked kernels include cracked wheat or rustic wheat flakes.

WHOLE KERNELS

Grains can be purchased as whole kernels. When whole wheat kernels are purchased, they are generally called *wheat berries*. Whole kernels add a contrasting crunchy texture and visual appeal to bread. There is also evidence that whole kernels, which the body absorbs and digests slowly, have desirable effects in the diets of diabetics.

Flour and Dough Additives and Treatments

Millers often add small amounts of additives to flour. Some of these additives are also available to the baker for mixing directly into dough. The types and amounts of additives that are allowed are strictly regulated by government agencies. By law, millers must label flour with the additives it contains.

There are several different types of flour additives. Some improve the nutrient content of flour and are required by law. Others improve dough handling or baking properties, or whiten the color of flour. A few of the main flour additives are described below.

VITAMINS AND MINERALS

Enriched flour is white flour that has iron and B vitamins added in amounts to equal or exceed those in whole wheat flour. Four B vitamins are added to enriched flour: thiamin, riboflavin, niacin, and folic acid. Certain other vitamins and minerals are

Why Is White Flour Enriched?

The milling process involves removing bran and germ from the endosperm. When this is done, vitamins and minerals, dietary fiber, and protein and fat from the bran and germ are removed. It is likely that other important unidentified nutrients are also removed. Flour enrichment replaces certain vitamins and minerals that are lost from milling. It does not replace all the lost nutrients.

Flour enrichment began in the United States in the early 1940s after government surveys found that a high incidence of disease was caused by certain vitamin and mineral deficiencies. The enforced enrichment of white flour virtually eliminated two of these diseases, beriberi and pellagra.

Periodically, the U.S. and Canadian governments re-evaluate the nutritional needs of North Americans. In the late 1990s, folic acid was added to the list of required vitamins and minerals added to enriched flour. Folic acid prevents certain birth defects, including spina bifida, and can also reduce the risk of coronary heart disease.

allowed as optional additives. Essentially all baked goods and pasta products in North America today are enriched.

NATURAL AGING

Natural aging occurs when freshly milled "green" flour is exposed to air for several weeks or more. In naturally aging flour, air is added to it. Air is a powerful additive, causing two main changes. First, it whitens the flour. Second, it strengthens the gluten that forms from flour.

Actually, the active ingredient in air is oxygen, which is considered an oxidizing agent. Oxygen oxidizes the carotenoid pigments in flour, changing their chemical structure and whitening them. Oxygen also oxidizes gluten-forming proteins, allowing them to form stronger gluten. Yeast doughs made from aged flour are easier to handle than those made from green flour, because doughs with stronger gluten are less sticky and less likely to tear when stretched. This, in turn, allows for higher volume and finer crumb on the baked bread.

Natural aging has a few disadvantages. First, it requires time, often several weeks or months. During this time, the flour takes up valuable silo space and is not paying the bills. Besides, the longer flour sits in silos, the more likely it will support mold growth or become infested with insects or rodents. Natural aging also can be inconsistent, and it is not as effective as many chemical bleaching and maturing agents. However, consumers sometimes prefer flours that have been naturally aged over those that contain bleaching and maturing agents. Naturally aged flours are often labeled "unbleached."

BLEACHING AND MATURING AGENTS

Maturing agents are additives that change the baking properties of flours. Maturing agents are added to flour by the miller or are found in many dough conditioners that are added by the baker.

Some maturing agents strengthen gluten, while others weaken it. Because the same term—*maturing agent*—is used to describe additives that have completely opposite functions, it can be confusing. In this text, maturing agents that strengthen gluten, such as potassium bromate and ascorbic acid, will be called *maturing agents that strengthen,* while those that do not will be called *maturing agents that weaken.* In either case, only very small amounts—parts per million—of maturing agents are necessary to cause the desired changes.

One maturing agent that strengthens is potassium bromate. When it is added to flour, the flour is said to be bromated. Potassium bromate has been in use since the early 1900s, and it is the standard against which all other maturing agents are judged. Despite this, potassium bromate is no longer allowed as a flour additive in Canada or in Europe. Potassium bromate is considered a carcinogen because it has been shown to cause cancer in laboratory animals. While still approved for use in the United States, its use is slowly diminishing. In California, products containing potassium bromate must carry a warning label.

Many companies are searching for "bromate replacers" to strengthen their flour. While several bromate replacers are available, *ascorbic acid* is one of the most popular. Another name for ascorbic acid is vitamin C. While ascorbic acid is not as effective as potassium bromate and it works a little differently, its use is increasing because of concerns over the safety of potassium bromate.

How Do Maturing Agents That Strengthen Work?

Maturing agents that strengthen gluten simulate natural aging. That is, they oxidize portions of glutenin and gliadin molecules, altering them so that more bonds form when gluten forms. The more bonds, the stronger, drier, and more cohesive the dough. When gases expand during final proof and oven spring, this stronger gluten stretches better without breaking. Loaf volume is higher, and the crumb is less coarse. For the most part, maturing agents that strengthen do not whiten flour. However, many are more effective than natural aging at strengthening gluten.

While potassium bromate and bromate replacers all work in a similar manner, they work at different times in the bread-making process. That is why commercial dough conditioners often contain a combination of maturing agents, to strengthen dough throughout the process. For example, some bromate replacers react rapidly, typically during mixing and makeup. In contrast, potassium bromate works primarily during final proof and oven spring, when strength is needed most. Ascorbic acid works consistently throughout bread production, just not as effectively as potassium bromate.

Bleaching agents whiten carotenoids. Two common flour bleaching agents are benzoyl peroxide and chlorine gas. *Benzoyl peroxide* is used in all types of flour because it is extremely effective at whitening and because it contributes no maturing effects. It is commonly used in bread, high-gluten, all-purpose, cake, and pastry flours that are bleached.

Chlorine is used in cake flour only. Besides whitening, chlorine improves the baking properties of soft wheat flour by substantially weakening gluten and by allowing starch to absorb water more quickly and easily. You can always tell from the label whether flour has been bleached, but you cannot necessarily tell which bleaching agent was used. Ask the manufacturer, if you would like to know.

Notice that chlorine's action on gluten is very different from the action of natural aging or maturing agents like potassium bromate. Chlorine is a maturing agent that weakens, and it is used on soft wheat flour. Potassium bromate and ascorbic acid are maturing agents that strengthen, and they are used on hard wheat flour.

AMYLASE

Amylase is one of several enzymes important in bread making. Recall from Chapter 2 that amylase breaks down starch into sugar. The sugar is good for yeast fermentation, for browning, for softening baked goods, and for slowing staling. While white flour does contain some amylase, the level is typically too low to be of much benefit, which is why amylase is sometimes added to flour by the miller. Or, the baker can add to a formula any of several ingredients that are rich sources of amylase, including malted flour, diastatic malt syrup, untoasted soy flour, or any number of dough conditioners that contain amylase.

MALTED FLOUR

Malted flour, or malt, is most often made from barley, but it can be made from wheat or other cereal grains. Malting means to sprout or germinate whole grain kernels under controlled conditions—as one might sprout beans or seeds. Once malted, the grain is heated to dry and then ground into flour. Certain brands of flour already contain malted barley flour, or the baker can purchase malt flour separately and add it to doughs.

Malt contains sugars, minerals, and valuable enzymes, including amylase. These provide many benefits to bread, biscuit, and cracker production. One benefit is that of improving yeast fermentation. Better yeast fermentation means better carbon dioxide production. Malted grains also add a characteristic sweet, nutty flavor to doughs, improve crust color, and delay staling.

DOUGH CONDITIONERS

Dough conditioners are also called *dough improvers*. They are off-white dry, granular products that look similar to flour. Dough conditioners are used in the pro-

What Are in Dough Conditioners?

While many brands of dough conditioners are available, most contain a mixture of the following ingredients:

- Emulsifiers, such as DATEM and calcium stearoyl-2-lactylate, for increasing water absorption and gluten strength. DATEM stands for diacetyl tartaric acid esters of mono- and diglycerides.
- Salts and acids, such as calcium carbonate or monocalcium phosphate, for optimizing gluten development by adjusting water hardness and pH. Calcium carbonate increases both water hardness and pH; monocalcium phosphate increases water hardness while it decreases pH. Monocalcium phosphate, an acid salt, is also present in many baking powders.
- Maturing agents that strengthen, such as potassium bromate, ascorbic acid, potassium iodate, and azodicarbonamide (ADA), for increasing gluten strength.
- Yeast foods, such as ammonium salts, to improve yeast fermentation.
- Enzymes, such as amylase, to improve yeast fermentation and browning, and to delay staling.

duction of yeast-raised products. Because they contain a mix of ingredients, dough conditioners perform many functions. They are particularly useful when good gluten development is necessary for high volume and a fine crumb, especially when flour quality is poor or when dough undergoes rigorous conditions. For example, large-scale bakery operations sometimes use dough conditioners to strengthen dough that gets rough-handled in automated equipment. Or, they may add dough conditioners to frozen doughs, where ice crystals damage gluten structure. Often, bakeries rely on dough conditioners to reduce mixing and fermentation time.

Dough conditioners should not be overused. Too much of a good thing yields poor texture and volume—and can be illegal. The United States and Canada both regulate many of the additives present in dough conditioners.

VITAL WHEAT GLUTEN

Vital wheat gluten contains a high amount—about 75 percent—of protein that is "vital," that is, protein that forms gluten when mixed with water. It is purchased as a creamy yellow powder. Vital wheat gluten is added to yeast-raised doughs to improve flour quality, to increase mixing tolerance, for a finer crumb, for improving volume, and to delay staling.

Commercial Grades of White Flours

Recall that the endosperm is the whitest part of the kernel and that it is the part of the kernel milled into white flour. Recall, too, that the endosperm contains all the gluten-forming proteins. No wonder that in North America commercial grades of white flour are defined by how much is pure endosperm. Flour that is very high in endosperm must be carefully milled, however, and this makes it higher in price. Of course, high-endosperm flours are whiter in color because they are relatively low in bran and germ "impurities." While these so-called high-quality flours are high in baking quality, they are lowest in nutritional quality.

Since wheat bran is naturally high in ash, the traditional way for manufacturers to confirm the grade of flour is to measure its ash content. While ash con-

How Is Flour Milled?

Flour milling has two objectives. First, it is a process that separates the endosperm from bran and germ. Second, it involves grinding the grain to fine flour. Ideally, milling separates out as much endosperm as possible without damaging starch granules, but this is difficult to do. In fact, commercial milling operations are able to extract only an average of 72 pounds of flour for every 100 pounds of wheat, for a so-called extraction rate of 72 percent, even though the endosperm makes up 85 percent of the wheat kernel. To accomplish the above objectives, the modern milling operation:

1. *Cleans* the kernels, to remove dirt, weed seeds, stones, and other debris.
2. *Tempers* the kernels by adjusting moisture content. Tempering toughens the bran and makes the germ more pliable, so the endosperm is easily separated from the bran and germ.
3. *Breaks* or crushes the kernels between corrugated rollers, loosening the endosperm from the bran and germ.
4. *Separates,* or "purifies" the endosperm from the bran and the germ, using sieves and air currents. The resulting coarse endosperm pieces are called *middlings.*
5. *Grinds* the endosperm middlings into flour between a series of smooth, reduction rollers.

These last three operations are repeated several times, producing streams of flour in which each progressive stream contains less endosperm and more bran and germ "impurities" than the last. These streams are selectively combined and sifted to produce commercial grades of flour. The flour is then naturally aged or treated with bleaching and maturing agents. Other approved additives may be blended in before the flour is packaged and sold.

tent is also affected by wheat variety and soil conditions, it does provide some indication of the amount of bran in flour and, therefore, of the flour's commercial grade. The following grades of flour apply to rye flour as well as wheat.

PATENT FLOUR

Patent flour is the highest quality of all commercial grades of white flour. Bakers often use the term *patent flour* to mean patent bread flour, but most flours sold today—whether bread, pastry, or cake—are patent flours. Patent flour is made by combining the first few streams of flour from the milling process. It consists of the innermost part of the endosperm and is essentially free of bran and germ. This makes patent flour lowest in ash and whitest in color. Different grades of patent flours are available, depending on which streams of flour from the milling process are blended. The highest-quality patent flour is called *extra short* or *fancy patent.*

CLEAR FLOUR

Clear flour is the lowest quality of all commercial grades of flour. It is milled from the outer part of the endosperm, made from flour streams that remain after patent flour is produced. While different grades are available, all clear flours are relatively high in bran, high in protein and ash, and slightly gray in color. A high grade of clear flour, called *first clear,* remains after the production of hard wheat first patent flour.

Clear flour is less expensive than patent flour. While it is higher in total protein than patent flour, the gluten formed from clear flour is typically of lesser quality than that from patent flour. First clear is commonly added to rye and whole grain breads. Its protein provides needed strength to low-gluten grains, while its gray cast is hidden by the dark color of the rye or whole grain.

STRAIGHT FLOUR

Straight flour is milled from the entire endosperm. It is made by combining all usable streams of flour from the milling process and contains bran and germ particles that are not easily separated from the endosperm. Straight flour is not commonly used by the baking industry in North America. French bakers, however, use a type of straight flour in breads.

Types of Patent Wheat Flours

Most flours purchased by the baker and pastry chef today—whether bread, pastry, or cake—are patent flours, milled from the heart of the endosperm. There are many differences among the various patent wheat flours. Some of these differences are due to the type of wheat used in producing the flour. Other differences occur because of differences in milling practices or additives.

BREAD

Bread flour is milled from either hard red spring or hard red winter wheat. It is high in protein—typically 11.5–13.5 percent protein—that forms good-quality gluten, essential for high volume and fine crumb in yeast-raised baked goods. Bread flour can be purchased unbleached or bleached. Sometimes it contains added malted barley flour to provide for better yeast fermentation, dough handling, and shelf life. Bread flour is typically used for pan breads, rolls, croissants, and sweet yeast doughs.

HIGH-GLUTEN

High-gluten flour is milled from hard wheat, generally hard red spring wheat. It is naturally high in protein—typically 13.5–14.5 percent protein—and often has potassium bromate or a bromate replacer added to it for even stronger gluten. It may be bleached. Like bread flour, high-gluten flour sometimes contains added malted flour. It is used almost exclusively for yeast-raised baked goods, particularly those requiring maximum strength and structure. Use high-gluten flour in bagels, hearth breads, and hard rolls.

Do not confuse high-gluten flour with vital wheat gluten, which looks like flour but is best thought of as a flour additive. And be careful when using high-gluten flour. Breads made with it can sometimes be tough and too chewy because of the high amount of gluten.

ARTISAN BREAD

Artisan bread flour, which is milled from hard red winter wheat, resembles French bread flour in its characteristics, that is, it is relatively low in protein (11.5–12.5 percent). The low protein content provides for a crisper crust and a crumb with desirable irregular holes.

Despite the low protein, the quality of protein in artisan bread flour must be high. Artisan breads undergo long fermentation periods to develop flavor. If gluten quality is poor, the gluten tears and the dough collapses from the rigors of a long fermentation.

Artisan bread flour often has a slightly higher ash content than patent flour. This creates a grayish cast on the flour and is thought to improve yeast fermentation and flavor. Artisan bread flours do not contain any bleaching or maturing agents.

PASTRY

Pastry flour is milled from soft wheat, generally from soft red winter wheat. It is low in protein—typically 7–9.5 percent—and is not usually bleached. Pastry flour is ideal for cookies and many pastries.

What If Bread Is Made from Pastry Flour?

If bread is made from pastry flour, it will not look or taste the same as bread made from bread flour. First, the dough will be softer, even though less water is required in the mixing. It will readily break and tear and be more easily overmixed.

Once the bread is baked, it will have lower volume. The crust will not brown as readily, and the crumb will be whiter. Air cells in the crumb will tend to be larger and more irregular. Expect a different flavor, and if the bread is stored over several days, it will stale faster.

Many of these differences are due to the lower amount and quality of protein in pastry flour compared with bread flour.

CAKE

Cake flour is milled from soft wheat, generally from soft red winter wheat. It is short or fancy patent flour, meaning that it comes from the absolute heart of the endosperm. This gives cake flour a finer granulation, whiter color, lower protein content—6–8 percent—and a slightly higher starch content than other flours. Cake flour is typically bleached with both chlorine and benzoyl peroxide, yielding a stark white color and a distinctly changed flavor.

Recall that chlorine is a maturing agent that weakens gluten and increases the ability of starch to absorb water. The importance of chlorine on the properties of cake flour cannot be overstressed. It is as much the chlorine treatment as the low protein content that defines cake flour.

How Important Is Cake Flour When Making Cakes?

Many cakes can be made successfully with pastry or bread flour, but light, sweet, moist, and tender high-ratio liquid shortening cakes cannot. High-ratio liquid shortening cakes are made from formulas that contain a high amount of water and sugar for the amount of flour. Without cake flour, these cakes would not rise, or more likely would rise and then collapse during baking and cooling. Here's why.

Recall that chlorine modifies the starch in flour, so that the flour absorbs more water than it otherwise would. This makes for thicker cake batters, even when large amounts of water are added. Thick batters are good at holding tiny air bubbles, for a light texture and a fine crumb. Recall, too, that starch is a structure builder. With so much water and sugar in high-ratio cake batters, and with weakened gluten, chlorine-treated starch becomes essential for keeping the cake from collapsing in the oven, so cake volume stays high and light.

What If a Formula Calls for All-Purpose Flour?

Not all professional bakeshops stock all-purpose flour. What should be done if a formula calls for all-purpose flour and none is available? For yeast-raised products, use bread flour instead. Additional water will be needed to form the dough, and longer mixing will be needed to develop the gluten. The dough will handle more easily, the bread will be higher than if it was made from all-purpose flour, and it will have a finer crumb.

For fine-textured, high-ratio cakes, substitute cake flour for AP flour. For most other cakes, such as gingerbread and carrot cake, and for all other products, including pastries and cookies, use pastry flour, or try a 60:40 blend of bread and cake flour.

ALL-PURPOSE

All-purpose (AP) flour is not always used by professional pastry chefs. However, it is sold in the foodservice industry as H&R flour, which stands for *hotel and restaurant* flour. AP flour typically has between 9.5–11.5 percent protein, but this can vary with the brand. While AP flour is often made from a blend of hard and soft wheat, this is not always the case. Some brands, like King Arthur flour, are made entirely from hard wheat. Other brands, like White Lily flour, are made entirely from soft wheat. AP flour comes bleached or unbleached, and may contain added malted barley flour.

Other Wheat Flours

WHOLE WHEAT

Whole wheat flour is sometimes called graham flour. It is a whole grain product because it contains all three parts of the kernel—bran, germ, and endosperm. Whole wheat flour comes in different granulations, from coarse to fine. It has a shorter shelf life than white flour because the bran and the germ are high in oil, which easily oxidizes to rancid off flavors.

Whole wheat flour is typically milled from hard red wheat, although whole wheat pastry flour, milled from soft red wheat, is available. Regular whole wheat flour is typically high in protein (11–14 percent, or more), but it does not form as much gluten as bread flour with the same or even higher protein content. There are several reasons for this. Sharp bran particles in whole wheat flour literally cut through gluten strands as they form. Also, much of the protein in whole wheat flour is from the bran and the germ, which do not form gluten. Finally, the wheat

What Is Wheat Flour?

Many bread labels include "wheat flour" as an ingredient. Wheat flour is not the same as whole wheat flour. The names are similar, but the flours are different. Whole wheat flour is a whole grain, milled from the whole wheat kernel. Wheat flour is another name for white flour, milled from the endosperm. It is called wheat flour to distinguish it from rye flour, corn flour, oat flour, or rice flour. This is a helpful distinction for those with allergies to wheat products, but it can mislead consumers into thinking that it contains all the health benefits of whole wheat flour.

Likewise, wheat bread is not the same as 100 percent whole wheat bread. Wheat bread typically has white flour as its main ingredient. While it contains some whole wheat flour, it often includes caramel coloring or molasses, for the darker look of 100 percent whole wheat bread.

germ contains components that interfere with gluten development. This means that yeast-raised doughs and baked goods made with whole wheat flour will be different from those made from white flour. Specifically, whole wheat bread doughs are less cohesive and resilient than those made with bread flour, and 100 percent whole wheat bread is denser and coarser than white bread. It is also darker in color and stronger in flavor.

To satisfy customers who are unaccustomed to the strong taste of bread made from whole wheat flour, bakers often blend about one-quarter to one-half part whole wheat flour to one part bread or high-gluten flour. As consumers become aware of the positive health benefits of whole grain baked goods, they will likely learn to appreciate the nutty flavor and denser texture of 100 percent whole wheat bread.

WHOLE WHITE WHEAT

Whole white wheat flour is made from hard white winter wheat, the newest class of wheat grown in North America. Whole white wheat flour has a sweet, mild taste and is golden in color. Because it is a whole grain, whole white wheat flour is just as high in dietary fiber as regular whole wheat flour.

DURUM

Durum flour is made from durum wheat. Durum wheat is not the same as common wheat, which is used in white and whole wheat flours. Durum wheat has a very hard kernel—harder than so-called hard wheat kernels—and it is very high in protein (12–15 percent). It is also high in yellow carotenoid pigments, which provide a desirable golden color to pasta products. Besides being used in pasta, durum flour is used in specialty baked goods, such as Italian semolina bread.

What Is Semolina Flour?

Durum wheat is commonly sold either as finely ground flour, called *durum flour,* or as a coarser granular product, called *durum semolina* or simply *semolina.* The particles in durum semolina are about the same size as those in farina. Today, the term *semolina flour* is sometimes used to mean *durum flour.*

Functions of Flour

PROVIDES STRUCTURE

Flour is one of two bakeshop ingredients that contribute to the toughening or structure building in baked goods, eggs being the other. Structure allows products to hold a new, larger size and shape as gases expand and leaven. It prevents products from collapsing once they are cooled and removed from the pan. Besides its importance in baked goods, flour provides "structure"—thickening, really—to pastry creams and certain pie fillings.

Gluten and starch are responsible for much of the structure-building properties of flour. Gluten is formed from two proteins in flour, glutenin and gliadin, when flour is mixed with water. While not as important as gluten and starch, pentosan gums also contribute to flour structure. Gums appear either to form their own structure or to interact with gluten.

Which of these structure builders—gluten, starch, or gums—is most important to a particular baked product depends on the type of flour and the formula used. For example, little, if any, gluten forms from cake flour or from nonwheat flours. Instead, starch, or starch and gums, becomes the main structure builder. On the other hand, products low in moisture, like piecrust and crisp cookies, inevitably rely on gluten alone for structure, because starch gelatinization cannot occur in the absence of sufficient water.

Even with flours that contain gluten, gluten is not necessarily the only, or the most important, structure builder. Take yeast-raised baked goods, for example. Gluten and starch share the role of structure building in these products. Gluten certainly is most important for developing structure in unbaked dough, but starch is arguably more important to the structure of the final baked product.

ABSORBS LIQUIDS

Ingredients like flour that absorb liquids are also called *driers*. Starches, proteins, and gums are the three main components in flour that absorb moisture (water) and oil, helping to bind ingredients together. Notice that the same components that form structure are also driers. The difference is that all proteins in flour—not just glutenin and gliadin—absorb moisture, while only glutenin and gliadin form structure.

Why Do Flours Differ in Absorption Values?

By one estimate, almost half the water in bread dough is held by starch, about one-third by flour proteins, and close to one-quarter by the small amount of gums in white flour. Starch absorbs most of the water in doughs because there is so much starch in flour. Yet, the best way to predict which of two flours will absorb more water is by comparing the amount of protein each contains. Proteins, including gluten-forming proteins, absorb fully one to two times their weight in water, while starch absorbs only about one-quarter to one-half its weight in water. This means that a small increase in protein has a noticeable increase in the amount of water absorbed in doughs. High-gluten flour absorbs more water than bread flour, and bread flour absorbs more than pastry flour.

This prediction works as long as the flour is not bleached with chlorine or otherwise treated. Recall that chlorine changes starch so that it absorbs more water. This is one reason why cake flour absorbs as much water as it does. Another reason is because cake flour is milled finer, and finer particles always absorb water faster.

The absorption value of flour is an important quality factor in bread baking. It is defined as the amount of water absorbed by flour when forming bread dough. High absorption values are desirable in bread baking because the added moisture slows staling. Higher water absorption also means that less flour is needed to make a loaf of bread, so if cost is a factor, this is an important point.

Water absorption values of most bread flours range around 50–65 percent, meaning that 1 pound (450 grams) of flour absorbs over 0.5 pound (225 grams) of water. While several factors affect the absorption value of flour, doughs that absorb more water typically have a higher protein content.

CONTRIBUTES FLAVOR

Wheat flours have a relatively mild, slightly nutty flavor that is generally considered desirable. Each has a different flavor, however. Expect clear flour, for example, with its higher protein and ash content, to have a stronger flavor than a fancy patent flour, like cake flour. Expect whole wheat flour to have the strongest flavor of all.

CONTRIBUTES COLOR

Flours vary in color. For example, regular whole wheat has a nut-brown color, whole white wheat flour has a golden color, durum has a pale yellow color, unbleached white flour a creamy color, and cake flour a stark white color. These colors carry over to the color of baked goods.

Flour also contributes protein, small amounts of sugar, and starches for Maillard browning—the breakdown of sugars and proteins—to a dark color on crusts. High-protein flours typically undergo more Maillard browning than low-protein flours.

ADDS NUTRITIONAL VALUE

Essentially all flours and grain products contribute complex carbohydrates (starch), vitamins, minerals, and protein. However, the protein in wheat is low in *lysine*, an essential amino acid. This means that wheat protein is not as nutritionally "complete" as egg or milk protein and is best supplemented with other protein sources for good health.

White flour is a poor source of fiber, but whole wheat flour and whole white wheat flour, being whole grain products, are good sources of insoluble dietary fiber from the bran, important in the diet.

What Is Celiac Disease?

Celiac disease is a disease of the intestinal tract brought about by the consumption of gluten (more specifically, the gliadin in gluten). When people with celiac disease consume gluten—even very small amounts of it—their bodies react by damaging the small intestine, where nutrients are absorbed by the body. Without proper absorption of nutrients, people with celiac disease—also called celiac sprue or gluten intolerance—become malnourished. They may develop a range of symptoms related to intestinal distress or to poor nutrition.

Because people with celiac disease cannot tolerate any amount of gluten, they must adhere strictly to a gluten-free diet for their entire lives. This means that they cannot consume any products that contain wheat. They also cannot consume any rye or barley, and oats may also be a problem for many.

Celiac disease is genetic, passed down from one generation to the next. Since it is the most common genetic disease in Europe—affecting one out of every 250 Italians, for example—it is likely that many Americans have celiac disease. While celiac disease remains largely undiagnosed in this country, diagnosis is available through a blood test or through biopsy of tissue from the small intestine.

As awareness increases about celiac disease, more gluten-free products are being developed. Preparing gluten-free baked goods can be a challenge, but it is not impossible. In place of wheat flour, gluten-free products usually contain some combination of rice, soy, potato, and tapioca flour. After some experimentation, it is possible to develop acceptable products for sufferers of celiac disease.

Storage of Flours

All flours, even white flour, have a limited shelf life. In fact, millers recommend that flours be stored for no more than six months. The main change that occurs is the oxidation of oils when flour is exposed to air. The result is rancid off flavors. While whole wheat flour is most likely to oxidize, even the small amount of oil present in white flour—just over 1 percent—eventually causes flavor changes. To avoid problems, rotate stock by following the FIFO rule—first in, first out—and do not add new flour to old. Flour should be stored covered and in a cool, dry area, particularly in the hot, humid days of summer. This prevents the flour from absorbing moisture and odors and from attracting insects and rodents.

Review Questions

1. Why is wheat so commonly used in the bakeshop? Why not flour from another cereal grain?
2. Identify the three main parts of a wheat kernel. Which is/are milled into white flour? Which is/are milled into whole wheat flour?
3. What components are naturally present in white flour? That is, what is the makeup of the wheat endosperm?
4. Which component in white flour—in the endosperm—is present in larger amounts than all other components combined?
5. What are the main differences between flours milled from hard wheat and those milled from soft wheat?
6. What is the difference between a flour and a meal? Provide an example of each.
7. What is added to flour to enrich it? What is lost from milling that is not replaced with enrichment?
8. What is meant by "green" flour?
9. What are the two main changes brought about by naturally aging flour?
10. What are the disadvantages of naturally aging flour?
11. Provide an explanation for the advantages of maturing agents that strengthen.
12. What is the standard maturing agent for hard wheat flours, the one that all others are judged against?
13. What is meant by a *carcinogen*? Which maturing agent has been shown to be a carcinogen?
14. Name a bromate replacer. How does it act differently from potassium bromate?
15. Are potassium bromate and bromate replacers more likely to be added to bread flours or to cake flours? Why?
16. Name the two most common bleaching agents. Which does nothing more than whiten flour? Which also acts as a maturing agent?

17. How is the action of chlorine different from the action of potassium bromate?
18. Is chlorine more likely to be added to bread flours or to cake flours? Why?
19. Why might flour contain a small amount of added amylase or malted barley flour?
20. What is meant by patent flour?
21. How does clear flour differ from straight flour? What is the main use for clear flour?
22. How much higher in protein is the typical high-gluten flour compared with the typical bread flour?
23. How is artisan bread flour different from regular bread flour?
24. How much lower in protein is the typical cake flour compared with the typical pastry flour? What else is different between cake flour and pastry flour that can explain their different properties?
25. Assume that a sample of whole wheat flour and one of white flour contain the same amount of protein. Provide three reasons why less gluten forms from the whole wheat flour than from the white flour. Be sure to explain your answers.
26. What is another name for wheat flour?
27. Which of the following are whole grains: whole wheat flour, wheat berries, durum flour, clear flour?
28. What are the differences in color, flavor, and dietary fiber between regular whole wheat flour and whole white wheat flour?
29. Why does whole wheat flour have a shorter shelf life than white flour?
30. Which of the following are usually milled from hard wheat and which from soft wheat: high-gluten flour, bread flour, artisan bread flour, pastry flour, cake flour, all-purpose flour?
31. Which contains more carotenoids, bread flour or durum flour? How does the amount of carotenoids affect the appearance of flour?
32. One function of flour is that it provides structure or toughening. What structure builder forms from glutenin and gliadin when flour is mixed with water? What else in flour provides structure?
33. Another function of flour is that it is a drier, meaning that it absorbs water and oil. What two main components in wheat flour absorb water? What else in flour is a drier?
34. What is meant by the absorption value of flour? How can you predict which of two flours will absorb more water?
35. You normally use regular bread flour in a formula and switch to high-gluten flour. Will you need more water or less water to fully develop the gluten? Explain your answer.
36. Why does bread flour absorb more water than pastry flour? Why does cake flour?

Exercises and Experiments to Try

1. Compare the properties of different flours in making chocolate chip cookies. Select a basic chocolate chip cookie formula that uses pastry flour. Prepare cookie dough from several different flours, including pastry flour, cake flour, bread flour, all-purpose flour, and whole wheat flour. Form, bake, and cool the cookies. Compare the cookies in height, spread, color, flavor, and texture. What do these differences tell you about each flour?
2. Compare the properties of different flours in making yeast-raised doughs and rolls. Select a basic lean dough bread formula that uses bread flour. Prepare the dough using bread flour, recording the amount of water needed to make dough of the proper consistency.

   Prepare additional doughs from various flours, including whole wheat flour, high-gluten flour, artisan bread flour, pastry flour, cake flour, and all-purpose flour. Adjust the amount of water for each flour so the consistency of the dough matches that made from bread flour; record the amount of water used with each flour. What does the amount of water tell you about the amount of protein in the flour? Why does cake flour require more water? Evaluate each dough for its consistency as follows: Press a finger on the dough and release. How well does the dough spring back? Take a small amount of dough and try to stretch it paper thin. Is it strong; that is, does it resist stretching? Is it cohesive; that is, does it form a good film and not tear easily?

   Time permitting, complete the bread-making process and bake the rolls, then cool. Compare the rolls in height, crust color, crumb appearance, flavor, and texture. What do these differences tell you about each flour?
3. Evaluate the effects of ascorbic acid (vitamin C) on the quality of yeast-raised dough and on baked rolls. Prepare dough using bread flour and ascorbic acid. Use about one-quarter of a 500-milligram tablet of vitamin C for every 2–3 pounds (1–1.5 kilograms) of flour. Crush the tablet and add it to the water used in the dough. Follow the guidelines in the previous experiment, comparing the dough and rolls made with bread flour and ascorbic acid to those made with bread flour and no ascorbic acid.