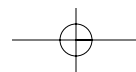
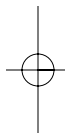
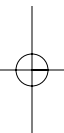




CHAPTER 1

WHEAT AND GRAIN FLOURS



Any discussion of baking must begin with its most elemental ingredient: wheat flour. Not only is wheat the heart and soul of bread but its special properties allow bakers to produce an astonishing array of products, from pastry to cakes and cookies. This will be the longest chapter in the book, as understanding this primary ingredient is vital to baking.

Wheat (and to a much lesser extent rye) flours do one thing extremely well that the flours of other grains cannot: create a gluten network. Gluten is the substance formed when two proteins present in flour, glutenin and gliadin, are mixed with water. Gluten is both plastic and elastic. It can stretch and expand without easily breaking. A gluten structure allows dough to hold steam or expanding air bubbles, so that yeasted dough can rise and puff pastry can puff.

As with many discoveries, the domestication of wheat and the making of risen bread was as much accident as intent. A truly remarkable series of fortuitous, mutually beneficial interactions between wheat and humankind helped to guarantee the success of both species.

## DOMESTICATION

Today's wheat is descended from wild grasses. Our hunter-gatherer ancestors certainly supplemented their diets with large-seeded wild wheat grasses for thousands of years, perhaps even cultivating the stands sporadically. Necessity, however, seems to have been the impetus

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for domestication of these wild grasses. A climatic shift about 10,000 years ago in the southern Levant (modern Jordan and Israel) brought warm, dry summers. Heat-resistant adaptive grasses thrived as other vegetable food sources diminished. Humans harvested the grasses more frequently, especially favoring the large-seeded, nutrient-packed wild wheats like einkorn and emmer.

Wild wheats are self-sowing. That is, the upper portion of the grass stem that bears the seeds, the rachis, becomes brittle upon maturity. It breaks apart easily in a good breeze or upon contact, scattering the seeds that will become next year's plants. Archeologists and agricultural scientists theorize that when humans gathered the wheat, most of the seeds fell to the ground. The seeds that made it home, attached by an unusually tough rachis, were mutants. Inadvertently, humans selected wheat that would not have survived natural selection: If the stem and kernels remain stubbornly intact, the grass is no longer self-sowing. Perhaps this new wheat was easier to transport back to camp in quantity, meaning a bit of leftover grain could then be planted conveniently close by. In a span of what archeologists estimate to be less than thirty years, humans and this now co-dependent strain of wheat set up house-keeping. Hunter-gatherers became farmers.

## TRANSFORMATION

Further selection by the farmer, combined with accidental crosses with wild grasses and new mutations, soon produced new wheat varieties. Selection continued to occur not only for obvious boons like bigger kernels and greater yields but also for ease of processing. The advent of a free-threshing wheat, where the seed or kernel separates relatively easily from the husk by mere agitation, was a critical step in the evolution toward bread wheat. Previously, parching—or heating the grain on a hot stone—was a favored method for removing the tightly attached husk from the kernel. The more palatable naked kernels were then softened in boiling water and the resulting gruel was eaten plain or baked later into flatbreads. And flat was most likely the name of the game: Parching at least partially denatures or cooks the gluten-

forming proteins in wheat, as well as destroys critical enzymes that help yeast convert sugar into starch. With free-threshing wheat, raw wheat kernels sans husk could be dried and ground, and the resulting “flour” had the potential to consistently produce risen loaves.

Wild yeasts had probably colonized grain pastes on occasion, but it was the availability of a wheat flour that could form a gluten network which made leavened bread feasible. The baker could replicate yesterday’s loaf by saving a bit of the old risen dough to use as leavening for the next day’s batch. The risen loaves had an appealing texture and aroma, as well as providing a more easily digestible form of nutrients. The Egyptians were using baked loaves of risen bread to start the fermentation process in beer by 5000 B.C.E. The brewery’s use of malted grain (usually barley or wheat, sprouted and then lightly toasted) in the beer ferment (wort) attracted the species of yeasts and their symbiotic bacteria that produce bread humans find most appealing. The yeasty dregs of the beer provided bakers with a reliable, predictable yeast variety that is the ancestor of commercial yeast used today. The species of wheat we refer to as bread wheat, *Triticum aestivum*, was the most favored grain throughout the Roman Empire. During the Dark Ages and up until the nineteenth century, wheat waned a bit, perhaps because it required more effort and time than its more self-sufficient cousins like rye and oats. Wheat returned to preeminent stature early in the twentieth century.

## MODERN WHEAT

Wheat is the second largest cereal crop in the United States; corn, with its myriad uses in industrial food and even nonfood applications, ranks first. Worldwide, however, wheat or rice, depending on the region, is the dominant food grain. It is wheat’s gluten-forming proteins, so inextricably linked with the development of baking, that, when combined with a willingness to adapt to new environments and new demands, help to explain its enormous popularity. It grows well over a wide range of moderate temperatures. It is relatively easy to cultivate and consistently produces high crop yields. The wheat kernel has high

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FIGURE 1.1 Emmer wheat.



FIGURE 1.2 Modern wheat.

nutritional value and good keeping qualities. Wheat can be processed with very little waste; what is not sold as flour is used for animal feed.

Genetically, wheat carries seven chromosomes to a cell. In diploid wheats like einkorn, there are two sets of chromosomes per cell. In tetraploid wheats—durum wheat being the best known example—there are four sets of chromosomes per cell. Hexaploid wheats have six sets of chromosomes and include bread wheat (*Triticum aestivum*), club wheats, and spelt wheats. *Triticum aestivum* accounts for 92 percent of the American wheat crop. Of the remaining percentage, about 5 percent is *Triticum durum*, or durum wheat, and 3 percent is *Triticum compactum* (red and white club wheats). Durum wheat is used almost exclusively in pasta making, and the club wheats are used in crackers and other products requiring flour with a low protein content.

## CLASSES OF BREAD WHEAT

Of the types of bread wheat grown here in the United States, 5 primary classifications are of major importance: **hard red spring wheat**, **hard**

**red winter wheat, soft red winter wheat, hard white wheat, and soft white wheat.** Hardness, growing season, and color are the three criteria used to draw the distinctions among these classes.

*Hard* and *soft* refer not only to the actual hardness of kernel of wheat (i.e., how hard it is to chew) but more specifically to the kernel's protein content: The hardest wheats genetically contain more protein and fewer starch granules. Hard wheats contain a layer of water-soluble protein around the starch granules; in soft wheats this trait is far less prominent. For the baker, this means that hard wheat flours produce doughs capable of the greatest gluten development. These hard or "strong" flours are ideal for bread. Hard wheats are grown where rainfall is low and the soil is more fertile, generally west of the Mississippi River and east of the Rocky Mountains up into Canada. Hard wheats account for about 75 percent of the American crop, but only a tiny amount of the Western European crop. This factor requires some juggling of flours when, for instance, adapting a classic French baguette recipe for American flour.

Generally, soft wheats have a high starch yield on milling and a low protein content. They are grown in areas of high rainfall and lower soil fertility, primarily east of the Mississippi River. Low-protein southern flours are deployed to their best advantage in their growing region's specialties—biscuits, pies, and cakes where tenderness is prized over strength. Beyond wheat's given genetic quotient of hardness or softness, environmental conditions determine the hardness of any given crop. Not only the overall protein content but also the quality and specific amounts of each protein present can be affected by seasonal variations.

*Winter* and *spring* refer to the two growing seasons for wheat. Winter wheats are planted in the fall. They grow for a very short period of time, become dormant during winter, resume growing in the spring, and are harvested in early summer. They are usually grown in areas that have relatively dry, mild winters, like Kansas. Winter wheat is generally higher in minerals. Spring wheats are planted in the spring and harvested in late summer. They are usually grown in areas with severe winters, such as Minnesota and Montana. Spring wheat usually contains more gluten than winter wheat of the same variety.

Color is the final determining criterion in classifying wheat. A slightly bitter red pigment is present in the seed coat of red wheats,

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WHEAT COMPARISON CHART (UNITED STATES)	
<b>Hard red winter wheat (HRW)</b>	Largest percentage (40 percent) of U.S. crop; moderately high protein content, generally used for all-purpose flours; 11–12 percent average protein content.
<b>Hard red spring wheat (HRS)</b>	20 percent of U.S. crop; highest protein common wheat class, primarily used in bread flour and high gluten flours; 13–14 percent average protein content, up to 16 percent. Subclasses are dark northern spring, northern spring, and red spring.
<b>Hard white wheat (HW)</b>	Newest class of wheat grown in U.S.; used in artisan breads, similar to hard red winter wheat, but with red pigment bred out, used to make mild-tasting whole wheat products; 11–12 percent average protein content.
<b>Soft white wheat (SW)</b>	10 percent of U.S. crop; protein content of about 10 percent, grown primarily in Pacific Northwest, preferred for flatbreads, cakes, pastries, crackers, and noodles. Subclasses are soft white, white club, and western white.
<b>Soft red winter wheat (SRW)</b>	Low-protein wheat usually grown in warmer, southern climates, primarily used in cake and pastry flours, crackers, and snack foods; 10 percent average protein content.
<b>Durum wheat</b>	Very hard, high-protein wheat used to make semolina flour for pasta; 15 percent average protein content. Subclasses are amber (pasta) and red (poultry and livestock feed).

similar to the tannins in tea; this trait has been bred out of white wheats. Hard white wheats are used primarily in whole wheat products where the bitter taste is undesirable, but a relatively strong flour is desired. Tortillas and bulgur are examples. Hard white wheat flour is also becoming popular with artisan bread bakers. Its higher mineral (ash)



content makes it ideal for long fermentation periods, and it has a slight natural sweetness. Red wheat generally has more gluten than white wheat.

## COMPONENTS OF THE WHEAT KERNEL

A wheat kernel consists of three basic parts: the bran, the germ, and the endosperm. The **bran** consists of several layers of protective outer coverings. The aleurone layer of starch-free protein that surrounds the endosperm is not truly a part of the bran, but usually comes off with it during the milling process. The bran, comprising 13 to 17 percent of the weight of the wheat kernel, contains relatively high amounts of celluloses (fiber), protein, and minerals. The **endosperm**, the part of the kernel beneath the bran covering, acts as a food reservoir for the growing plant. It composes 80 to 85 percent of the grain's weight, including the aleurone layer removed with the bran. The endosperm consists of starch granules embedded in a matrix made up of gluten-forming proteins. In its center, near one end, is the germ. The **germ**, composing 2 to 3 percent of the kernel's weight, is the embryonic wheat plant. It contains high levels of proteins, lipids, sugars, and minerals.

## GRIST MILLING

Milling is the mechanical process in which wheat kernels are ground into a powder or flour. Beginning with simple crushing in a mortar

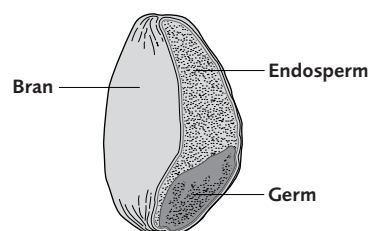


FIGURE 1.3 Components of the wheat kernel.

and pestle, humans rapidly devised more and more efficient ways to accomplish this feat. The ancient Egyptians advanced to grinding the grain (grist) between two large flat stones (grooved or dressed to let the fine flour particles escape), moving in opposite directions and driven by animal power. Grist mills soon employed the power of running water to drive wheels. Stone-ground flour is *de facto* whole-grain flour; only when the flour is bolted or sifted will it become white stone-ground flour. The finer the sieve, the whiter the flour will be; it will, however, always contain some of the finely crushed wheat germ. Flour was usually produced in just one session of grinding—only with the advent of new harder wheat varieties was it necessary to pass the grist through again, this time with the stones set closer together. Stone-ground flour is generally produced without generating excessive heat, which is thought to be beneficial to both flavor and performance of the flour in breads. Also, the presence of small amounts of finely ground wheat bran (with its relatively high amounts of pentosans) is believed to increase moisture content in breads and helps prevent staling. Wheat germ provides a nutty, pleasant taste and aroma to the baked loaf.

Flour must be oxidized before it is ready to use (see oxidizing and bleaching, pages 14–15). This can be done by adding a chemical to the flour or it can be done naturally by letting the flour age. Natural aging, or oxidizing, takes three to six weeks. In whole-grain or stone-ground white flours, natural aging of flour can be problematic since both the thiol groups and the fats (wheat germ oils) oxidize. When fats oxidize, they become rancid; therefore, the aging must be done at a cool temperature. Once purchased, naturally aged whole-grain flours must be stored in the refrigerator if they are not used in a timely fashion. Use freshly milled whole-grain flours promptly—or, even better, grind the grain as needed if you work on a very small scale—to prevent off flavors from developing.

## ROLLER MILLING

For the past hundred years, roller milling has been used to produce the majority of flours. It is especially suited for producing white flours.

Roller milling, in addition, creates the capability to produce hundreds of “streams” of flour from one single grain stock. Flour producers can combine various streams to produce flours of a desired protein content or particular makeup.

In either grist or roller milling, the kernel is first cleaned in a series of operations designed to remove dust and any foreign particles. In roller milling, the wheat kernel is then dried and rehydrated to a specific moisture content designed to optimize the separation and grinding processes that follow. At this point, different strains of wheat can be blended to produce a stock with the desired characteristics. The first pass between heavy ridged metal rollers revolving toward one another serves to break the kernel into its component pieces; this first **break roll** produces some flour, chunks of endosperm (termed variously “shorts,” “overtails,” or “overs”), bran, and germ. The process is repeated another four or so times, using rollers with successively smaller grooves that are set closer and closer to one another. These are all break rolls, designed to separate the endosperm from the bran. The germ is quite plastic owing to its high oil content and is easily flattened into a single plug on the first couple of passes. It is usually removed by the third break roll (despite its high nutritive content of lipids or fats) because it easily becomes rancid and will cause spoilage in the resulting flours. The bran is somewhat flexible and progressively detaches from the endosperm in large flakes. After each break roll, the stock is sifted or bolted to remove the flour, the smaller and smaller pieces of endosperm (or **middlings**), and bran pieces. After about the sixth break, practically all that remains is bran. Bran is removed from white flours since its particles have sharp edges that can disrupt gluten formation.

## FLOUR GRADES

At this point all the middlings (endosperm fragments) plus minute amounts of germ and bran are sifted and then ground into flour between smooth rollers in a series of seven to nine reduction rolls. Flour, middlings, and bran are again produced every pass, separated out by bolting, with the middlings continuing through further rolls.

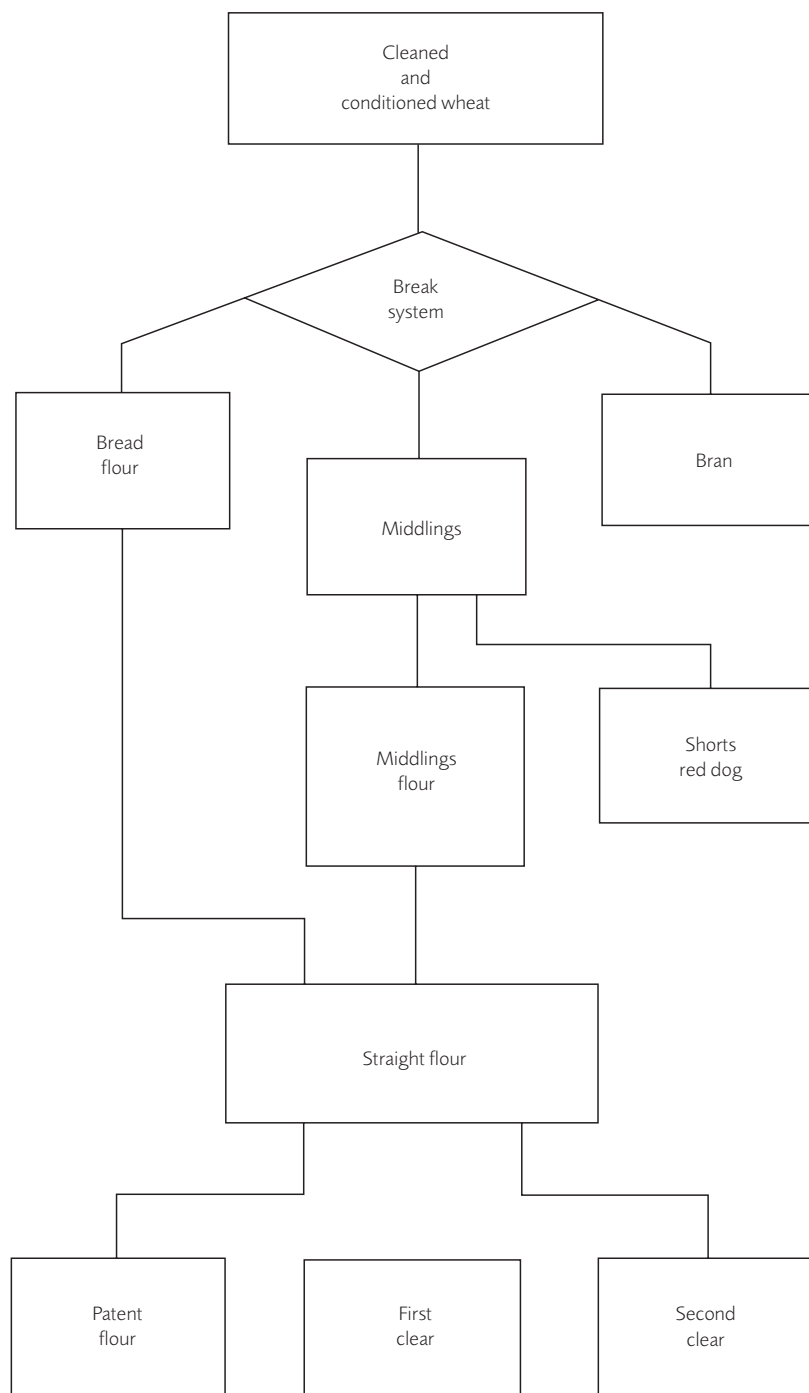


FIGURE 1.4 The milling of wheat into flour. Reprinted from *A Treatise on Cake Making*, by permission of Standard Brands, Inc., copyright owner.

Different streams of flour may be separated out at any point to be sold. All flour streams contain individual starch grains, small chunks of the protein matrix in which the starch is embedded, and bigger chunks of the protein matrix with some of the starch granule still attached. Different streams of flour will have different ratios of starch to protein, however, and may be kept and packaged separately for this feature. The first flour streams separated out in the breaking process contain the least bran and germ; they are more “refined.” These are sold as patent flours. Within this class are further grades ranging in refinement (or absence of bran and germ) from fancy to short to medium to long. Subsequent streams of refined middlings produce flours known as clear flours. These also have grades from fancy clear to first clear to second clear. Lower grades of flour are usually quite dark and are most frequently used in combination with other flours, particularly in rye bread baking.

## EXTRACTION RATE

From a given batch of 100 pounds of grain, only 72 pounds of straight flour result. A straight flour is one in which all the various streams of flours are combined. Of the remaining 28 pounds, the separated bran or germ may be added back in varying percentages to make “whole wheat” flour. The final shorts—a mixture of bran bits, plus some pulverized endosperm and germ—is sold as animal feed. The 72 pounds of flour from 100 pounds of grain is referred to as a 72 percent **extraction rate**, meaning there is little or no bran or germ in the finished flour. European flours generally have a slightly higher extraction rate—between 75 and 78 percent. The inclusion of more bran and germ, along with the fact that European wheat is softer, means that French bread flour has about 2 percent less protein than American bread flour. Many artisan bread bakers making hearth breads prefer a higher extraction flour (one with more residual bran and germ) for its flavor and baking quality. Home bakers can achieve roughly the same substance by adding a small percentage of sifted whole wheat to their bread flour.

## FRACTIONATION

Since the 1950s a technique has existed called fractionation that can produce flours that are significantly higher or lower in protein content than the parent stock. Flours with different ash contents, particle size, or amylase activity (see page 20) than the parent stock can also be produced. It's a complicated process involving air streams and centrifugal force, but it basically uses particle size and density to sort for the desired characteristics.

## FLOUR AND OXIDATION

Flour that is freshly milled, or green, does not make great bread. The dough is lacking in extensibility, and is slack and difficult to handle. The resulting baked loaves tend to have coarse crumb and poor volume. Aging the flour over a period of several months with repeated stirring so that fresh flour is continually exposed to air corrects this problem. The process of oxidation thus occurs naturally; as the flour sits and is repeatedly exposed to air, many of the thiol groups on the protein molecules oxidize, or give up their free sulfur to an oxygen molecule. If not oxidized, these thiol groups can disrupt the sulfur-to-sulfur protein bonds that help give a dough elasticity as gluten is developed; these are the bonds that allow a dough to snap back into shape after being stretched. In unaged flour, thiol groups grab onto the free sulfur when the dough is stressed, the original sulfur-to-sulfur bond is broken, and the dough becomes slack.

## BROMATION AND ALTERNATE METHODS OF OXIDIZING

As in any business, a period of waiting such as for oxidation is viewed as a hindrance to profit. And natural oxidation results are not always completely uniform. Large milling operations since the early 1900s

have been sidestepping this process by the addition of inexpensive chemical oxidants. A few parts (75) per million of potassium bromate was generally thought to strengthen the dough throughout the handling process as well as allow for shorter fermentation times, reduced mixing times, and faster processing. Any flour that has potassium bromate added is known as bromated flour. However, since the early 1990s, potassium bromate has been suspected as a possible carcinogen; in 1991, California began mandatory labeling of all products containing potassium bromate. Although potassium bromate is still legal, the following substances have also been FDA approved as alternate oxidizing agents in flour: ascorbic acid (vitamin C), azodicarbonamide (ADA), iodate of calcium, and iodate of potassium. In Germany and France, the only oxidizing agent for flours allowed by law is L-ascorbic acid. Ascorbic acid is frequently used in the United States along with other oxidizing agents to improve gluten quality.

## BLEACHING

Bleaching flour with one of several agents removes the xanthophyll, a carotenoid pigment that causes the flour to be slightly yellow in color. Some, but not all, bleaching agents can also perform the function of aging or oxidizing the flour. Chlorine dioxide, chlorine, and acetone peroxide are used to both bleach and age flour (see Pyler, p. 353). When bread flour is bleached it is usually done for color purposes alone: The bleaching agent, usually benzoyl peroxide, does not oxidize the flour. All-purpose flours are available bleached or unbleached, and cake flour is always bleached with chlorine. Bleaching with chlorine oxidizes both the starches and protein present in flour at the relatively low levels employed in cake flour. This oxidation improves dough strength, which seems antithetical to the idea of soft cake flour.

Chemically bromated and/or bleached flours are designed to perform particularly well in industrial-scale breadmaking where their abilities to minimize fermentation and mixing times and make the dough withstand high-speed mixing are viewed as a bonus. Artisan breadmaking, with its long fermentation periods and relatively gentle handling of the dough, usually does not employ bromated or bleached

flours. The bleach residues may also adversely affect the balances of yeast and bacterial cultures in wild yeast starters. Debate continues over whether the chemicals used in bleaching and bromating pose any sort of health risk. Many experts contend that bromating agents, especially, are reduced to iodine salts upon baking; the same salts are found in very small quantities in sea salt, and are closely related to iodized or table salt, and thus, harmless.

Bleaching affects the behavior of starch in flour much more advantageously than it affects the behavior of protein. Cake flour, milled from soft red winter wheat with a low-protein, high-starch content, profits from a certain degree of bleaching in several aspects. Chlorination makes the wheat starches in cake flour able to absorb more water, resulting in moister baked goods. (In bread flours, on the other hand, protein rather than starch is primarily responsible for flour hydration. The high protein content [needed to build gluten structure] of bread flour ensures adequately hydrated dough. Bleaching bread flour would be superfluous and counterproductive.)

Cake flour is traditionally bleached with chlorine gas and is left a bit acidic. Fat will stick to chlorinated wheat starch, but not to unchlorinated starch. Air bubbles in creamed cake batters are dispersed primarily in fat; distribution of bubbles is thus more regular and a finer texture is produced when bleached (cake) flour is used. The acidity will cause the structure of cakes to set faster as the starch gelatinizes sooner in the oven, reducing baking time and keeping the cake moister. Acidity also discourages the development of gluten, important in making tender cakes.

## OTHER ADDITIVES/IMPROVERS/ CONDITIONERS

Some flours can be deficient in enzymes, particularly beta amylase, that convert starch into sugars. Since yeast feeds on sugar, not starch, this can be a problem. To correct an enzymatically unbalanced flour, either malted barley flour (from germinated grain) or fungal amylase is added at the flour mill. To perform this correction on your own, add



$\frac{1}{2}$  teaspoon of enzymatically active (diastatic) malted barley flour per 1 cup of flour. If bread doughs are fermenting sluggishly or have poor volume, the flour may not be enzymatically balanced. Too many enzymes produce a slack, sticky dough that results in gummy bread.

Calcium phosphate may be added to bolster the leavening action of baking powder in doughs or batters that contain significant amounts of acidic ingredients like buttermilk.

Mold inhibitors like vinegar or other acids can discourage microbial action. Certain bacteria form thick-walled spores that are not killed by baking; they form sticky, yellowish patches in the bread that pull apart into ropelike strands. The addition of propionates (salts of propionic acid) inhibits the growth of both mold and rope-forming bacteria.

Most of the vitamins present in wheat (particularly B-vitamins and vitamin E) are concentrated in the bran, the germ, and the aleurone layer of the endosperm that is removed with bran during milling. Whole-grain flours, flours with higher extraction rates, and the end streams of flours will contain more vitamins. Cake flour, with its lower extraction rate, contains the fewest vitamins. To offset the loss of these vital nutrients, the government dictates that flour be enriched with iron, B-complex vitamins, thiamin, riboflavin, niacin, and folic acid. Vitamin E is volatile, subject to oxidation and rancidity, and so it is not added to the flour. Flour is usually fortified by the miller.

## COMPONENTS OF FLOUR

The wheat grain is characterized by a high carbohydrate content (about 70 percent), relatively low protein content (9 to 13 percent), low moisture content (11 to 13 percent), small amounts of lipids, a number of enzymes, and fiber, minerals, and vitamins. The carbohydrates are primarily starch and cellulose. The proteins include, of course, glutenin and gliadin, the gluten formers, as well as minute amounts of other proteins. Lipids are present primarily in the germ and bran of the wheat kernel and are not a significant factor in white flours. Minerals make up what is known as the **ash content** of the flour. The ash refers to the amount of mineral residue left behind in a controlled burn of a flour sample. Vitamins, predominantly the B-complexes and vitamin E,

are again present most significantly in the bran and germ, but are removed during milling and may be added afterwards.

## C A R B O H Y D R A T E S

Starch, dextrins, cellulose, pentosans, and various free sugars make up the carbohydrate content of wheat. Milling removes almost all the cellulose as well as most of the pentosans. Most fiber in wheat is in the cellulose. Damaged starch granules (altered during the process of milling) play an invaluable role in structural development in leavened breads and batters. In yeast doughs, the amylase enzymes attack damaged starch first, producing sufficient simple sugars (carbohydrates) to feed the yeast during fermentation. Damaged starch also affects the formation of dextrins during baking and the moisture level of the finished product. Ratios exist for the optimum level of damaged starch found to be beneficial in flour, directly correlating with the protein content of the flour. Flour contains a small amount of sugar; melbiase is converted by an enzyme in yeast, melbiase, to produce simple sugars directly available to the yeast as food. The pentosans in flour may amount to 2 to 3 percent, primarily in the tailings or end runs in milling. Pentosans can aid in producing bread with a higher moisture content and reduced staling.

## P R O T E I N

Flour is produced from the endosperm of the wheat. The endosperm contains about 80 percent of the total amount of protein in the whole kernel. **Gliadin** and **glutenin** make up most of this and are usually present in almost equal proportions. Variations in their relative proportions may significantly affect gluten formation. Gliadin seems to be a key player in the volume attained in breadmaking, imparting viscosity and extensibility. Glutenin provides elasticity and strength to the dough. Both of these proteins are directly affected by both environment and genetics. Environmental conditions influence protein quantity while genetics seem to determine protein quality. In other words, even low-quality wheat can produce some high-protein flours.

The quality of wheat is determined, rather tautologically, by how well it performs in the task it has been given. Good cake flour will rely upon the same factors to produce lovely tender cakes that would produce horrible, flat, gummy bread. American hard wheat flours, with their high protein content and ability to absorb large amounts of water, may make it difficult to produce a European hearth bread with crisp, brittle crust and open crumb. Just remember that each type of flour was created with a specific purpose in mind—how well it lives up to that promise determines how “good” it is. Quality flours perform well over a broad range of protein contents.

## GLUTEN FORMATION

When wheat flour is mixed with water and stirred or kneaded, the glutenin and gliadin proteins not only bond with the water but also link and crosslink with one another to eventually form sheets of a flexible, resilient film called gluten. Gluten can trap air and gases formed by yeast, causing bread to rise. As the yeasts feed on the sugars, they produce a liquid containing both alcohol and carbon dioxide. The carbon dioxide is released upon contact into the air bubbles, enlarging them. In baking, the alcohol converts to gas, enlarging the bubble even more—producing oven spring. Flexible starch granules held in place by the gluten network also bend around the air bubble. The gluten protein eventually cooks, releases its water into the starch, and begins to firm. This provides the structural framework for the loaf of bread. As the starch gelatinizes, it also becomes semi-rigid, giving even more support. In cakes or quick breads, however, too much gluten can be detrimental. The efficacy of chemical leaveners can be compromised when gluten prevents them from bubbling through a batter. Protein content determines how much water a flour can absorb—the greater the amount of protein, the more hydration is possible.

## ENZYMES

Enzymes are biochemical proteins that act as catalysts, meaning they have the ability to instigate chemical changes without themselves

being changed. Flour naturally contains small amounts of enzymes called **amylases** and **diastases** that can break down starch into simple sugars needed by yeast. Wheat flour does not contain sufficient sugar for optimal yeast growth and gas production, but the enzymes break down damaged starch into maltose and glucose. Frequently wheat flour is deficient in these enzymes. As a corrective measure, additional enzymes are introduced. The resulting flour is enzymatically balanced. The first source of these enzymes was malted wheat flour, then malted barley flour, and most recently fungal amylase. Sprouted, or malted, grain increases the presence of diastase enzymes and is particularly beneficial to naturally leavened doughs. Enzyme activity confers a number of boons. Crust color improves from **Maillard reactions** (browning reactions) enhanced by increased amount of sugars. Flavor is improved by the same Maillard reactions. Reactions induced by the addition of small amounts of certain heat-stable amylases present, for instance, in rye flour or in fungal amylase can continue well into baking, producing sweetness without the detrimental effects of added sugar on yeast fermentation and gluten structure of a dough. An excess of these enzymes, however, will cause too much of the starch to be converted to sugar and result in a flat loaf. One other class of enzymes, the proteases, is significant. An excess of protease enzymes, which prefer to digest gluten proteins, will result in slack, sticky dough.

## LIPIDS

Only 1 to 2 percent of lipids make it past milling into flour. The glycolipids seem to aid the gluten-forming proteins in retaining the carbon dioxide gas produced in fermentation. In effect, they seem to be sealing the burst gas cells as the proteins denature during baking, preserving volume. Lipids can also bind glutenin to starch to gliadin; this very thin lipid layer increases plasticity and oven spring. They may also help in preserving freshness in the baked bread for the same reason. Other lipids—free fatty acids such as lineoleic and linolenic acids and the monoglycerides—are oxidated by the enzyme lipoxxygenase, naturally present in wheat, during the process of dough mixing. This causes a

natural bleaching of the carotenoids, brightening the crumb, imparting a pleasantly nutty flavor, and binding those troublesome thiol groups that cause poor dough performance.

#### MINERAL CONTENT / ASH

Minerals are the inorganic substances present in wheat that are derived from the soil. Wheat flour contains anywhere from 1 to 2 percent minerals. Ash content (see page 17) is affected by the soil itself, rainfall, type and amount of fertilizer, and so on. Once again, during milling most of the wheat kernel that contains significant proportions of minerals is removed with the bran and germ. The minerals that remain in white flour are actually in excess of what minerals occur in the endosperm. Thus, the ash content of the flour is directly related to the amount of bran particles in the flour. High-extraction flours generally have a high ash content. A level of at least .44 to .48 percent of ash in bread flour is viewed as favorable, and many artisan bread bakers prefer higher values. High ash content ensures the presence of minerals that cause the gluten formed to be more tensile.

## FLOUR VARIETIES AND HOW TO CHOOSE

Flour performs a number of functions in baked goods: It provides structure; it binds and absorbs; it affects keeping qualities; it affects flavor; it imparts nutritional value. Not every flour is going to do the same job well, so over the years “flour” has become many, many “flours.” Pastry chefs today are presented with a bewildering array of flours tailored to meet specific requirements in different products. The big variable at the heart of this proliferation is protein content (and quality) and its consequences for gluten development. Modern milling practices can further modify the inherent ability of a specific wheat through choices in blending, milling, and processing.

**FLOUR GUIDE****MILLING TERMS**

These terms are how millers define their flours to the baking trade. Patent, clear, and straight flours all have their own subgrades (fancy, short, long, first, and second) that refer to the percentages of various streams they may contain. All of these terms refer to hard wheats.

**PATENT FLOUR** Single streams of flours from early on in the milling process; considered more refined as they contain less bran and germ residuals; low in minerals (low ash content); more expensive.

**CLEAR FLOUR** Also called common flour, less refined and higher in protein than bread flour; milled from extreme outer layer of wheat endosperm; slightly darker in color; 16 percent protein content causes it to be frequently used with rye flour to alleviate its lack of gluten.

**STRAIGHT GRADE FLOURS** Combination of all streams of flour created during milling process; protein content around 11.5 percent is ideal for hearth bread; higher ash/mineral content good for long fermentation processes.

**HIGH EXTRACTION FLOUR** Flour from the end runs or streams at the mill containing more of the residual wheat bran and germ; light tan in color; highly flavorful; extraction rate anywhere from 75 to 95 percent; protein content is usually lower due to the inclusion of the fractions of flour that do not contain

the gluten-forming proteins. Flours with an extraction rate between 75 and 78 percent are ideal for artisan breads. Very high extraction flours are used with other flours.

**BAKER'S TERMS**

Bakers use the following terms to describe the standard blends of flour they would ordinarily employ for a specific purpose. Most of these flours are available in some form to the retail buyer; the home consumer may not be able to find one quite so specific, but can usually blend a decent concoction from the other flours.

**ALL-PURPOSE FLOUR** Available bleached or unbleached; blend of hard spring wheat and soft winter wheat; protein content between 9 and 11 percent.

**BREAD FLOUR** Available bleached or unbleached, bromated or not; hard red spring wheat; protein content between 11.5 and 13 percent; usually includes enzymatic corrective; slightly granular to the touch.

**HIGH GLUTEN FLOUR** Unbleached; dark spring northern wheat; 14 percent protein content; used in combination with bread or all-purpose flours; good for highly machined doughs or in combination with grain flours lacking gluten.

**WHOLE WHEAT FLOUR** Unbleached; contains all of the wheat grain including bran, germ, and endosperm; several

types are available: soft whole wheat flour with low protein content used in chemically leavened batters like muffins and pancakes, protein content around 11 percent; whole wheat from hard red winter wheat used primarily in bread, protein content around 13 percent.

**PATENT DURUM FLOUR** Fine silky grind of extremely hard cold weather wheat; unbleached; pale yellow in character; protein content of around 12 percent; particularly good in hearth breads.

**PASTRY FLOUR** Available bleached or unbleached; soft winter wheat; protein content around 9 percent.

**COOKIE FLOUR** Soft wheat flour; protein content between that of pastry flour and cake flour; usually only a bakery item.

**CAKE FLOUR** Always bleached and enriched; soft winter wheat, particularly from warmer growing regions; protein content around 7.5 to 8 percent; ideal for cakes and biscuits.

#### **SPECIAL FLOURS**

**ARTISANAL BREAD FLOUR** Unbleached; lower protein content of around 11.5 percent; performs in hearth breads much like lower protein European flours; equivalent to U.S. flours with higher extraction rate (75 to 78 percent).

**VITAL WHEAT GLUTEN** What is left over when starch has been removed from wheat flour in a washing process; pro-

tein content about 40 percent; used in breads prepared with other grains that lack gluten-forming proteins.

**GRAHAM FLOUR** Similar to whole wheat flour, but the bran particles have been very finely ground; for use in cookies or soft rolls and breads.

**ORGANIC FLOUR** Always unbleached and unbromated; growing conditions are not yet standardized; expensive, up to twice the cost of regular flour; good for beginning naturally fermented starters for bread due to high content of microflora.

**WHEAT BRAN** Removed in milling, sold separately; contains all of the cellulose in wheat that provides fiber; used extensively in health breads and in muffins.

**WHEAT GERM** Removed in milling, toasted and sold separately; is a wonderful addition in pancakes, cookies, and muffins; provides nutty, pleasant taste in bread; spoils quickly, especially if not properly refrigerated.

**SELF-RISING FLOUR** Available as cake flour or as all-purpose flour to which baking powder and salt have been added in ratios ranging from ½ teaspoon to 1½ teaspoons double-acting baking powder and ¼ teaspoon to ½ teaspoon salt per cup of flour.

**SOUTHERN ALL-PURPOSE** Includes White Lily brand with a very low protein content approaching that of cake flour; usually bleached; protein content around 9 percent.

*(continued)*

**FLOUR GUIDE (Continued)**

**INSTANT FLOUR** Includes Wondra brand, a low-protein pregelatinized (partially precooked) wheat flour with added malted barley flour; used in pie crusts for tenderized effect and to thicken sauces without clumping.

**STRONG AND WEAK** Terms used by bakers to describe the ability of a particular flour to form gluten, akin to the hard and

soft description of the wheat kernel.

Both sets of terms are directly related to the protein content of the wheat endosperm that allows the flour to form gluten. Strong flours can form the good-quality, elastic gluten that makes for great bread. Weak flours have less gluten-forming capacity and are best suited to cakes and pastry.

## STORAGE

Flour should be stored in a cool, dry, well-ventilated area free of odors. Flour can readily absorb odors that spoil the taste of the finished baked product. A storage temperature somewhere between 60 to 70°F is ideal. Wheat germ, wheat bran, or flours that contain significant amounts of them should be refrigerated as they quickly become rancid.

## NON-WHEAT FLOURS

### RYE FLOUR

Rye is another member of the wild grass family whose cultivation stretches back into antiquity. Rye is hardier than wheat in challenging climates and is frequently grown either side by side or in rotation with wheat to ensure some sort of grain crop. More rye than wheat was grown during the Middle Ages, and it is still a favored grain in the colder European climates, especially the Scandinavian countries.

Whole rye flour does not have enough of or the right kinds of gluten-forming proteins to make light bread by itself. Rye does contain a roughly similar amount of protein, even both of the gluten-forming proteins, glutenin and gliadin, but in proportions smaller than in wheat. The gliadin in rye, however, doesn't interact with the glutenin



in the same way as wheat gliadin does in forming gluten. Most of the structure provided by rye flour in bread comes from the interaction of its proteins with **pentosans** (gumlike substances) and the gelatinization of its starch. Rye doughs containing more than 20 percent rye flour rely on the viscosity of starches and pentosans to trap carbon dioxide gas and provide structure. Any air trapped in the dough is not enclosed in gluten cells that can expand, but in an unstable foam. As the loaf of rye bread enters the oven, in the absence of gluten, the gelatinized starch on the outside of the loaf forms a sort of skin that aids in gas retention. Wheat flour is added in varying amounts to compensate for the gluten deficiency in rye.

Another problem in making light, well-shaped rye loaves arises in the heat-stable nature of an enzyme, amylase, that breaks down starch. During baking, the starch granules in both wheat and rye uncoil from their crystalline structure and are basically dissolved in the water. This process creates a kind of gel that sets as it cooks, providing structure to the baked bread. In wheat breads, the amylase enzyme is denatured or made inactive before starch gelatinization takes place. In rye bread, however, this enzyme is far more heat-stable. This means the amylase is free to attack not just the initially available damaged starch, but the starch made available by gelatinization. The result is that way too much starch is converted to sugar and the bread flattens, sags, and becomes heavy as the loaf undergoes hydrolysis. The action of rye amylase is inhibited, however, in an acid environment, especially in conjunction with salt. Traditional rye breads are made with sour starters; the low pH slows down enzyme action and protects the starch until the rye amylase is finally denatured during baking. Long fermentation also makes the rye more digestible. (The word *pumpernickel* has its rather humorous roots in two German words, *pumpfern*, “intestinal wind,” and *nickel*, “demon” or “sprite.”)

Rye flour comes in a wide variety of styles and sizes. Commercial rye flour is usually not made from the whole grain; instead, different parts of the endosperm are separated out during the milling process. Most of the mineral content, and hence the ash percentage, of rye is contained in the outermost layer of the endosperm, just inside the bran coat. Ash content is significant in breadmaking as it can appreciably affect the vigorousness of natural fermentation. White rye flour is milled from

the center of the endosperm. Cream or light rye flour is from the next layer of the endosperm. Dark rye flour comes primarily from the outer portion of the endosperm. Rye is also available as a meal: ground from the whole kernel. Rye meal is available in various particle sizes, ranging to fine, medium, or coarse. The coarse grade of rye meal is what is commonly referred to as pumpernickel flour. Rye chops are the equivalent of cracked wheat. Rye bread is traditionally strongly flavored with caraway seeds. Its baking quality is dependent on its enzyme content, which can vary widely from one batch of grain to another. Whole-grain rye flours are particularly sensitive to deterioration in storage; not only do they smell rancid but their performance in doughs is compromised as well.

Rye flour is extremely hygroscopic, meaning that it will absorb moisture from the environment. For this reason, rye breads have an extremely high moisture content that translates to very good keeping qualities. It also means that the baking breads take longer to set. Occasionally rye breads are not sold until the following day.

## RICE FLOUR

Rice flour is produced by grinding uncoated rice. It is used like pastry flour and is a good substitute for wheat flour in food allergy cases as long as the appropriate changes are made in the recipe to accommodate the lack of gluten. Rice flour is traditionally used in some shortbread recipes owing to the fine, sandy texture it produces.

## CORN MEAL AND CORN FLOUR

Cornmeal is available in two colors, yellow and white. Yellow cornmeal is a good source of vitamin A; white cornmeal is not. Either color of cornmeal is available in either a fine or coarse grind. Old-process cornmeal is prepared by grinding the whole corn kernel with the exception of the outer bran coat. New process, or degerminated cornmeal, has the germ and all the bran removed. Degerminated cornmeal keeps better, as the fats in the germ do become rancid quickly. Old-process cornmeal, however, has superior flavor and food value. Cornmeal is used in

some hearty breads, in muffins, and, of course, in cornbread. Corn flour is very finely ground degerminated cornmeal. It is used in crepes, cakes, muffins, and breads in combination with wheat flour.

### TRITICALE

An extremely hardy and nutritious hybrid of wheat and rye cereal grasses, triticale is used primarily for animal feed in the United States. Triticale flour does not make good bread unless it is used in combination with wheat flour; it performs similarly to rye. Bread made from triticale alone will have poor volume and a gummy texture. The gluten formed by triticale is of poor quality; doughs are more extensible, but less elastic.

### SOY FLOUR

Soy flour is made from soybeans, a member of the legume family. Soybeans are cultivated worldwide, but only as a primary food crop in Asia. Elsewhere, soybeans are more frequently used to produce oils, both edible and industrial, and as animal feed. Since soybeans contain high levels of easily digestible protein and oils and are an excellent source of amino acids, their popularity and use in other forms are beginning to increase in Western culture. Soy flour is frequently used in creating baked goods for those people who have allergies to wheat protein. Soy flour is usually defatted to prevent spoilage and heat-treated to remove the beany taste. When added to wheat bread in a percentage below 3 percent, defatted soy flour does not have any appreciable effect on the dough's performance or taste, other than a slight increase in water absorption (see Pyler, pp. 401–403). Beyond this rate, it begins to disrupt gluten formation and good structure; soy flour has no elastic properties whatsoever. It is used in small quantities as a replacement for milk in breadmaking to improve texture and decrease staling. In doughnut making, up to 15 percent soy flour can be used to reduce oil absorption and improve shelf life. It can be added to chemically leavened baked goods in a higher proportion than to yeasted products.

## B A R L E Y

Barley cultivation most likely began at the same time as wheat. Barley has two advantages over wheat: a short growing season and an extremely hardy nature. Flatbreads made from barley, a grain that has no gluten-forming proteins, were popular until the Roman era, when wheat was favored. During the Middle Ages, especially in the Scandinavian countries, barley was a staple food of the lower classes. In Middle Eastern countries today, barley is still widely used. Western countries use barley primarily as animal feed and to make malt—pulverized, sprouted grain. Malted grain contains more of an enzyme that converts starch to sugar and is used to supplement wheat flour to ensure a good fermentation rate in yeasted breads. Malt is also used, of course, to transform grain mashes into beer or liquor.

Barley is available in a number of forms for use in soups, pilafs, and breads. Hulled barley has been husked, but retains most of its bran; it is the most nutritious form of barley. Scotch or pot barley is triple-polished to remove the bran (and many of its nutrients). Pearled barley is polished even more and in the process loses not only its bran but its germ as well. Most of the vitamins, minerals, and fiber are also removed by this point. Barley flakes are made from the flattened whole seed and used like rolled oats. Barley flour is available in a range of whole-grain composition; whole-grain barley flour has a darker color and pronounced nutty flavor.

## O A T S

Oat products are available in a number of forms for the baker: rolled oats, quick oats, steelcut oats, and oat flour. Oats are processed differently from wheat and rye; an adherent husk must be removed from the grain before it can receive further processing. Once the oat berries or groats are hulled, they are heat-treated to both soften the groats and to inactivate the enzymes that would eventually cause the fats to become rancid. Rolled oats are groats that have been flattened by passage between two rollers. They are used primarily in cookies, whole-grain breads, streusels, and granola. For quick oats, the groats are cut into pieces before being flattened; they require shorter cooking than rolled

oats, but are used almost interchangeably in baking. Steelcut oats are quick oats that have not been flattened; they are used in specialty breads for their nutty flavor and nubby texture. Oat flour is either a by-product of the above processes or is milled intentionally as an end product from the whole groat. Oat flour is most frequently employed in chemically leavened products such as pancakes, waffles, and muffins. Since it has almost no gluten, it is not a primary bread ingredient.

### **M I L L E T**

Millet is an umbrella term for several unrelated cereal grains, including common millet, pearl millet, sorghum or milo, and teff. All of these grains have been cultivated for many thousands of years, throughout the world. Generally, all millets are small in size, but are very high in protein, around 16 to 22 percent. Millet grows well in hot, arid climates and even thrives in poor soils. In parts of Asia it is an important food source, usually consumed as a porridge, unleavened bread, or beer. Western cultures tend to use cooked millet as an ingredient in healthy, high-nutrition wheat breads.

### **P O T A T O F L O U R**

Potato flour (ground dried potatoes) or dehydrated potato flakes can be added to wheat flour in low percentages (typically around 3 percent). It can aid in moisture retention, act as an extender, and help to keep bread soft as it ages. Potato flour contains 8 percent protein and is higher in thiamin, riboflavin, and niacin than wheat flour.

### **B U C K W H E A T**

Buckwheat is not a cereal grain at all, not even a grass. It is a member of the same family as rhubarb and sorrel. Its kernels are actually achenes, or dry fruits, similar to the “seeds” in strawberries. Buckwheat grows well in cold climates and in poor soils. Eastern European

cultures (especially Russian) and the Japanese use buckwheat most frequently. Buckwheat flour is used in a number of breads and pancakes, or blinis, as well as noodles. The whole buckwheat grain may be cooked in the same way as rice and is most familiar in the preparation known as kasha, a type of pilaf.

#### MISCELLANEOUS SEEDS / LEGUMES

Peanut flour and cottonseed flour are high in protein with good amounts of vitamins, particularly the B-complexes. They are added in small percentages (under 5 percent) to increase the nutritive content of bread produced on a large commercial scale without changing the texture or flavor greatly.

#### S P E L T

Spelt wheat is one of the ancestors of modern bread wheat. It is not free-threshing wheat; its hull requires considerable effort to remove. Hulled spelt wheat can be prepared like rice. It has a mellow, nutty flavor and a higher overall protein content than common bread wheat. Spelt protein, however, is seemingly tolerated better by people with wheat allergies. Spelt flour can be substituted for wheat flour in recipes.

#### Q U I N O A

Quinoa is an annual plant of a family that includes beets, chard, and spinach. It is native to South America and has been grown in the Andes for over 5,000 years. It is very hardy, resistant to both cold and drought. Quinoa's many tiny seeds resemble a cross between millet and sesame seeds. Quinoa provides more nutrients than cereal grains; it is high in protein, magnesium, iron, and potassium. Quinoa can be used whole, cooked or soaked, in wheat health breads. Ground quinoa can be substituted for a small portion of the wheat flour in breads,

cookies, and muffins. It is usually not used alone since it does not form gluten.

## **A M A R A N T H**

Amaranth is an herbaceous plant native to the Americas. It was farmed extensively in Mexico before the Spanish conquest. The seeds are rich in nutrients with a distinctive, slightly spicy flavor. Amaranth can be used whole, cooked or soaked, in health breads and is also available as a flour. Amaranth has no gluten-forming proteins; it could conceivably be used alone only in waffles, pancakes, or perhaps cookies. Any instance when some gluten formation is needed for structure, however, as in breads and cakes, it should be used in combination with wheat flour.

