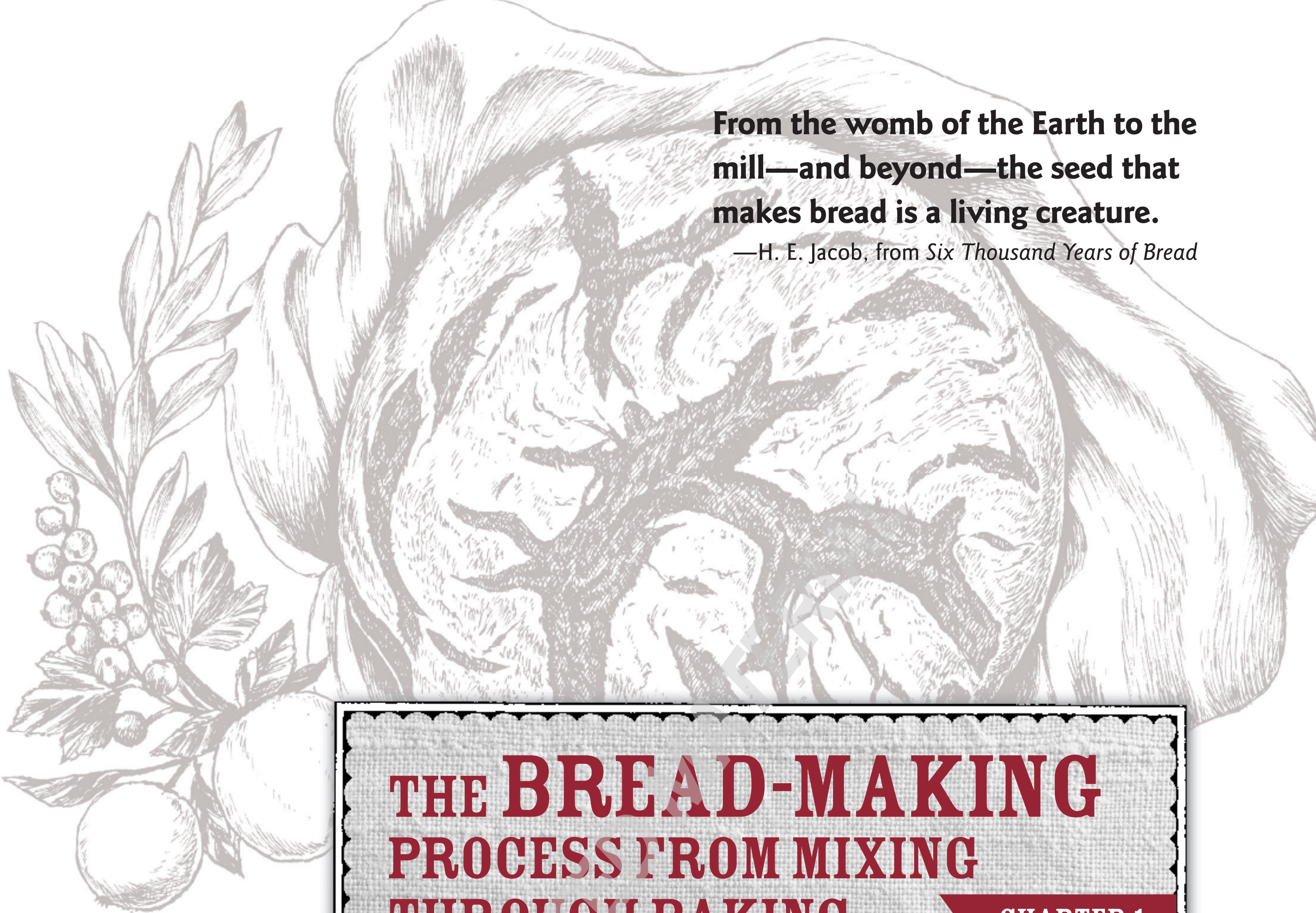


From the womb of the Earth to the mill—and beyond—the seed that makes bread is a living creature.

—H. E. Jacob, from *Six Thousand Years of Bread*

THE BREAD-MAKING PROCESS FROM MIXING THROUGH BAKING

CHAPTER 1

IN THE DISCUSSION THAT FOLLOWS, we will look at each phase of the bread-making process, from the scaling of ingredients through the cooling of the baked loaves. Each step of the way we will examine not only the importance of the individual step, but also try to see how each step affects the ensuing steps.

Volumes could be written on many of these individual steps, but for our present purposes, we will endeavor to present a clear overview and confine the discussion to those aspects of bread production that have a direct impact on the daily life of the baker. Some of the information presented will be scientific; I am, however, a baker and not a scientist, and the goal is to undertake explanations that are useful and applicable to the daily reality of the baker.

The bread-making process can be divided into 12 separate steps. Occasionally, one of the steps, such as folding, might be eliminated. Some steps, like bench resting or final fermentation, are fairly straightforward; others, like mixing and baking, are enormously complex. Bear in mind from the outset that whatever the baker does to his or her dough will have an impact on every step in the rest of the process.

STEP ONE: SCALING

The first step in bread making is the scaling of ingredients. Correct and accurate scaling is necessary in order to achieve consistency and uniformity of production. When scaling, we are also calculating the final dough yield, and accuracy will prevent under- or overproduction. Therefore, cost control is a small but significant aspect of scaling. Measuring ingredients by weight and not by volume is the only way to ensure accuracy, and a reliable scale is an invaluable tool for every baker.

STEP TWO: MIXING

The first step in proper mixing has nothing to do with actual mixing at all: It involves the simple determination of the water temperature required for the mix, which is calculated by computing the desired dough temperature (described fully beginning on page A-20). Consistent baking results require many things, not the least of which is consistent temperature control. The importance of spending a few moments calculating water temperature in order to achieve mixed dough in a correct temperature zone cannot be overstressed. Once we have determined the water temperature, the actual mixing can proceed.

Life in the mixing bowl is complex indeed, and it begins the moment the flour and water come together and mixing ensues. Mixing accomplishes a number of important goals. Most simply, it brings about a uniform distribution of ingredients so they are evenly dispersed throughout the dough. Other aspects of mixing are far more complex. During the mixing of wheat-based doughs, gluten is formed. At first, the gluten molecules in flour are randomly bunched, haphazardly oriented in all directions. During mixing, the molecules are stretched and become aligned in more or less straight lines, and it is this stretching and aligning of the gluten strands that develops the dough's strength. Mixing the dough so that the gluten is adequately developed enables the dough to stretch well, to resist ripping, and to hold trapped carbon dioxide gases that are produced during yeast fermentation, which in turn enables bread to emerge from the oven with good volume and lightness. It's a bit more complicated than that, however. There are, in fact, two proteins in wheat flour that combine to form gluten—glutenin and gliadin—and they have seemingly opposite natures. (Rye flour contains the proteins gliadin and glutelin, but due to the presence of pentosans the mixing requirements as well as the dough properties for rye breads are very different than those for wheat bread. The method for mixing rye

AT GRAM'S HOUSE

MY EARLIEST FOOD MEMORIES MAY BE OF BREAD. One of my grandmothers was Polish or Russian, depending on where the ever-changing boundary line happened to be drawn at a given time. As a boy, I visited or was visited by my grandparents most every weekend. If we went to Gram's house, there was sure to be a boundless array of home-cooked foods, which fit effortlessly into my seemingly bottomless belly. If my grandparents visited us, there was less food, but food was still the hub of the visit. No matter where the visit took place, Gram always had bread. The funny thing was, I never saw an entire loaf. In those days, people still bought bread by the pound. Gram would order a few pounds, which were then dutifully hacked off some endless loaf and wrapped in paper. The bread was crusty, dense, and fragrant. At times, we would get the end portion of this mother lode of loaves, which had a paper union stamp. We'd rip the stamp off, but usually some paper remained on the loaf. We didn't care; we ate and ate.

breads is discussed in detail beginning on page 210). Glutenin helps develop dough structure and the elastic quality of the dough, that is, the dough's resistance to stretching. Gliadin provides dough with its extensible characteristic, that is, its ability to be stretched. Both are necessary, and proper mixing is required to develop the potential for both elasticity and extensibility. These two qualities, in balance with each other, enable the dough both to resist stretching (elasticity) and to be stretched without tearing (extensibility). And the balance between these discrete aspects continues to be important throughout the entire bread-production process.

Here's an example: Imagine that you are shaping a baguette, and the small 12- or 14-ounce (340- or 400-g) dough piece is about to be rolled to 24 inches (60 cm) long, with an even diameter along its entire length. If there is an excess of elasticity (this could be caused by either insufficient bench rest after pre-shaping, or by using a very-high-protein flour and mixing to too high a development), the dough will be fighting you throughout the rolling process—and in all likelihood it will win! Ripping and tearing, resisting and defying, by the time it is at full length it will look like it needs a hospital or a lawyer. (Now, imagine having a hundred of these pieces to roll!) At the other extreme, the dough on the bench has too much extensibility (from a weak flour insufficiently mixed, or from too long a rest after preshaping). It doesn't feel like dough at all; it's a body with no bone structure, it's a worm, a mollusk! It offers no resistance whatsoever as you roll it out, and it's flat and misshapen, and will remain so through the bake. It's obvious that what we really need is the middle ground—dough that is both relaxed and taut, and which can be rolled out fully, under some degree of resistance.

It's one thing to talk about gluten molecules, but I've never seen a baker mix with a microscope in hand as the dough spins. We mustn't neglect the actual hands-on aspect of mixing and the visual and tactile changes that occur. Once we put the dough ingredients into the mixer and turn it on, we begin to hydrate the flour. It is important, regardless of what style of mixer is used, that the initial process of mixing takes place on first speed. During this period of the mix, the outer surface of the starch granules become moistened, the ingredients take on cohesion, and the dough begins to form. Once the ingredients are incorporated, generally from 2 to 3 minutes after mixing begins, turn off the mixer and feel the dough (this is also a good time to taste a piece of dough to make sure salt was added). It will be sticky, shaggy, and loose, lacking in strength, smoothness, or elasticity. Pull on a handful—it will shred away from the bulk of the dough, offering little resistance. And so it should, for at this stage of mixing we are concerned above all with the *consistency* of the dough, not its *strength*.

It is woefully common at this point in the mix for inexperienced bakers to conclude that the dough is too wet and to add flour. What seems to be excessively loose dough early in the mix, however, will soon transform once the second phase of mixing—gluten development—is accomplished. Extra flour added early on has ruined many a dough. Only by feeling the dough throughout the mixing process can we understand—through our hands—the considerable change from loose and shaggy to firm, elastic, and developed.

Once the consistency of the dough has been checked and corrected as necessary, the gluten-development phase of mixing proceeds. Usually, the mixer is turned to second speed and the dough mixes to its appropriate development. Reach in and yank on the dough again. A well-mixed dough will resist your pulling; it will have strength and muscle, and at the same time be supple and have some swing to it. Some bakers pull off a small piece of dough and look at the "gluten window" by gently stretching the dough to the thinnest sheet possible (sometimes called the "windowpane test"). This is one way to gauge gluten development, but be careful: If the window is completely clear and the gluten totally developed, the dough has almost certainly been overmixed. Appropriate development does not necessarily mean full gluten development, and as we shall see, many factors affect the amount of time a dough mixes on second speed, and consequently how fully we should develop the gluten in the mixing bowl. If our only goal is dough volume, a lot of yeast and maximum gluten development in the mixer is the method of choice. Maximum volume is one thing, however, and maximum flavor is another, and a mixing technique that favors the utmost volume will also compromise optimum flavor.

With each revolution of the mixing arm, oxygen is incorporated into the dough and a new portion of the dough is mixed by the arm. The incorporation of oxygen is important, as it contributes to the strengthening of the gluten network. An excess of oxygen, however, has a devastating effect on dough. Carried to an extreme, the dough becomes overmixed, and the gluten bonds, after first stretching and developing elasticity, begin to break down; the dough becomes shiny and sticky as water is released back into the dough, elasticity decreases, and the entire structure of the dough unknits. Even before reaching that point of breakdown, an excess of oxidation can occur, reducing flavor and therefore bread quality.

OXIDIZING AND OVEROXIDIZING

WE READ AND HEAR ABOUT the need to oxidize flour before using it in bread production and, which seems somewhat contradictory, the need not to overoxidize dough in the mixer. An explanation of the needs and precautions for oxidizing flour may serve to clarify the topic.

When white flour is first milled, it must be oxidized before it is used in baking (because of superior nutrition and flavor, freshly milled whole grains can and should be mixed as soon as possible). During this period of oxidization, and later when the flour is mixed with water in the mixer, things happen on a molecular level that have an important impact on the flour's baking quality. (As a baker and not, distinctly not, as a scientist, I give this miniature explanation to bakers and distinctly not to scientists.) At that misty molecular level of things, quite complex and not entirely understood processes occur in freshly milled flour. After milling, gluten proteins are gradually strengthened by the natural development of disulfide bonds. What are known as thiol compounds, also present in freshly milled flour, serve to block the development of disulfide bonds. In the presence of oxygen, thiols are put out of commission. Without sufficient oxidation, not enough disulfide bonds will form, the gluten matrix will not develop fully as the dough is mixed, and the quality of the finished bread will suffer from poor volume and weak structure.

This oxidizing of the flour is best achieved simply by letting it age, from roughly three to four weeks, before baking with it. Oxygen gently penetrates the flour during this natural form of aging, stabilizing the flour and improving its baking quality. (In earlier days, flour was stored in wooden barrels or cloth sacks, both of which allowed oxygen to enter and age the flour. Double-walled bags are the norm in bakeries today, so natural aging may be a bit slower than when flour was stored in wood or cloth; nevertheless, modern bags are an improvement over cloth sacks, since the droppings of nocturnal mice on the cloth did not provide a desirable addition to the flour within.) It is only when flour has sufficiently aged that it attains its optimum baking potential. Flour that is unaged or underaged is known as "green flour." Breads made with green flour have poor elasticity, poor oven spring and loaf volume, coarse crumb texture, and a thick, unpleasant crust. Here's a dilemma: Many modern mills produce well over a million pounds of flour each day—can you imagine the miller's reaction if you asked him to store a three weeks' supply of flour so that it was properly aged before leaving the mill? An alternative to the natural aging of flour is to chemically treat it and thereby *artificially* oxidize it. In spite of the considerable negative effects on flour and baked breads, chemical aging by the addition of bleach or other artificial oxidants is common throughout the United States (see "Flour Additives," beginning on page A-16, for a lengthier treatment of bleach and its consequences).

When flour is placed in the mixer and dough is mixed, oxygen is incorporated, which assists in the development of the gluten bonds. The action of the dough hook or mixing arm is adequate to provide this oxidizing of the dough. Overoxidizing the dough from overmixing, however, has negative consequences for a number of reasons. First, when overmixed, the gluten structure breaks down and the dough weakens in strength, loses elasticity, and becomes shiny and sticky as dough water, at first absorbed during mixing, is released. Second, the carotenoid pigments, which are naturally present in unbleached flour and help to impart the creamy color to it along with the wheaty aroma necessary for ultimate bread flavor, are destroyed by excessive mixing. Just as egg whites, which have a slight yellow hue, become snowy white when mixed into meringue—simply by the addition of oxygen from the mixer whip—so too will bread dough in the bowl transform from a subtle creamy color to toothpaste-white when it suffers from overmixing. One further consideration is that a warm dough oxidizes more quickly than a cool dough; careful attention to dough temperatures is imperative.

What, then, are the considerations regarding dough development that the baker should be aware of during the mixing phase? At one extreme we have the following: The dough is mixed on high speed to maximum gluten development, and it reaches a state of maturity in the mixer, due to the excess incorporation of oxygen as well as to the dough's high level of physical development. Dough strength is at a peak, and bulk fermentation consequently must be all but eliminated. Carotenoid pigments, which give unbleached flour a creamy color and fragrant aroma, are oxidized out of the dough due to the excessive mixing. The development of full bread flavor, which is always a lengthy process, is not possible. At the other extreme, imagine that the dough is mixed very slowly, on low speed only (or by hands or even feet, as was the case for many centuries). Gluten development is at a minimum, as is oxidation of the dough. Bulk fermentation lasts for many hours, punctuated by a number of folds, and the dough slowly reaches maturity. The carotenoids are not oxidized out of the dough, and the bread flavor is superb. Loaf volume, however, is comparatively small, because of the relative lack of physical dough development.

Then there is the middle ground: The dough is mixed to moderate gluten development in the bowl. Physical development is furthered both by time—sufficient bulk fermentation—and appropriate folding. The carotenoids have not suffered from overoxidation in the mixer, and contribute their part to bread flavor. Bread volume is good. What has been achieved by this method is a balance that respects both the need for gentle mixing in order to preserve the fragile carotenoids, as well as the need for adequate bulk fermentation to encourage the fullest possible bread flavor, dough strength, and keeping quality.

There is no doubt that dough of proper strength is necessary for the best bread. There are alternatives, however, to achieving complete development of the dough in the mixer, with its attendant consequences of excess oxidation and too-speedy dough maturation. Long fermentation times and the use of pre-ferments both increase the acidity of the dough through the development of organic acids; one benefit of this increased acidity is the strengthening of dough structure. Another effective method of increasing strength is to fold the dough, which has an immediate and considerable effect. The concept of the relationship among the degree of mixing, the resulting dough strength, and the fermentation requirements of that dough is an important one. Like so many parts of bread production, it is difficult to precisely quantify the parameters, for the boundaries seem amorphous and ever shifting. With careful attention to mixing and careful observation of the results (that is, dough performance), the baker can arrive at a practical, empirical understanding of cause and effect.

MIXING TIME

Many other factors affect mixing time. Here is a brief discussion of some of them.

The type of mixer. Spiral mixers, oblique (axis) mixers, and planetary mixers are the most common types used by professional bakers in the United States, and stand mixers (similar in action to planetary mixers) predominate among home bakers (hand mixing should not be overlooked, and two effective methods are described in Chapter 7). Not only are the revolutions per minute different in each speed for each mixer, the mixing arms affect the dough differently. Spiral mixers are highly efficient, and develop the dough comparatively quickly without an excess of oxidation. Being so efficient, they also have the ability to overmix a dough quite quickly, and so require careful timing. Oblique mixers are slower and gentler (seeing them spin, I have always believed they were designed to simulate the kneading performed in former times by two bakers standing opposite each other at a dough trough, literally up to their elbows in dough as they mixed). As with spiral mixers, the bowl in an oblique mixer rotates along with the mixing arm. Because of the action of the mixing arm, oblique mixers, in spite of their gentleness, incorporate a greater amount of oxygen into the dough than spiral mixers do, and overoxidation can potentially be more of a problem. Planetary mixers operate with the mixing arm descending vertically from above the bowl, which does not rotate. They are highly regarded (and rightfully so) as all-purpose mixers, since, unlike spiral or oblique mixers, they can accommodate not only dough hooks, but paddles and whips as well, and therefore can mix a great variety of products, from sponge cakes to cookie doughs. Although they are fairly inefficient as bread mixers, great bread can nevertheless be made using them. With any mixer, knowing the rpms at different mixer speeds is important. Calculating the friction factor of the machine is equally important (this is discussed in "Desired Dough Temperature," beginning on page A-20).

The amount of dough in the bowl. I used to believe that when the mixer was three-fourths rather than half full, the dough developed more quickly. I was mistaken. It's true that with more dough, the greater mass means that the dough ferments more quickly once mixed, but

AUTOLYSE

THE REPOS-AUTOLYSE TECHNIQUE was developed by Professor Raymond Calvel, the twentieth century's foremost expert on French bread production. Loosely translated, autolyse is a "self-smoothing rest" period. It is beneficial in French bread production, as well as in the production of many naturally leavened sourdough breads (excepting rye-based sourdoughs, since the gluten-lacking rye doughs would deteriorate during the rest period). The technique, thoroughly detailed by Professor Calvel in 1974 *(L'influence de l'autolyse naturelle des pâtes en panification)* involves the slow-speed mixing of just the final dough flour and water of a formula. Salt, yeast, and pre-ferments are not included in this phase (with the exception of liquid-levain or poolish, as detailed below). Once the flour and water are incorporated, the mixer is turned off, and the dough is covered and left to rest for 20 minutes to an hour. During the rest period, the flour fully hydrates, and the gluten bonds, somewhat magically, continue to develop in spite of the lack of mechanical mixing. After the rest period, the remaining dough ingredients are added, and mixing resumes, usually on second speed. Much less mixing time is required to develop the dough; in my experience the overall mix time is reduced by as much as 50 percent. In fact, the dough will develop rather rapidly after the autolyse phase is complete, and also can break down quite quickly—you must keep a close eye on it as it mixes. Since the autolyse method reduces the overall mixing time, oxidation of the carotenoids is minimized, resulting in baked loaves that are more aromatic, with a creamier and more open crumb, as well as more pronounced cuts. Professor Calvel put it more succinctly when he described French bread made using the autolyse technique as "*plus séduisant*" (more seductive).

Some degree of acidity is a general characteristic of naturally leavened breads, and not infrequently the level of acidity can be high enough so that the resulting tightening of the dough structure impedes the bread's potential for full expansion in the oven. The autolyse technique can serve the baker well in this instance for the following reason: once the flour has been hydrated and the autolyse phase begins, the flour enzyme protease begins its work of degrading protein bonds. While an excess of protease activity could result in a shreddy dough lacking in structure, a modest amount can improve loaf volume. Consider this: when we use high-protein flours or make sourdough breads that are high in acidity, it's difficult for the expanding loaf to break through all that strength and acidity once it enters the oven, and loaf volume suffers. Using the autolyse technique, the dough has an easier time expanding in the oven due to the slight reduction of dough strength. Last, when making breads containing lots of whole-wheat flour, during the autolyse the bran has an opportunity to absorb more dough water. This also has a favorable impact on loaf volume, because during the final mixing of the dough there is less of a cutting action of the bran on the gluten strands.

Salt is not added to an autolyse, because its tightening effect on the gluten network acts against the development of the gluten bonds that is achieved during the autolyse rest phase. Yeast is not added to the autolyse, because if it were, fermentation would begin, and with it the incipient development of acidity which, like salt, tightens the dough. Pre-ferments are generally not added because of the presence of both yeast activity and acidity. The exceptions to this are when a liquid levain or a poolish is used. In these cases, the high percentage of overall dough water that is present in the pre-ferment is enough that, if the remaining flour and water were mixed without including the pre-ferment, there would be insufficient water to hydrate the flour; small pebbles of unhydrated flour would persist in the dough, right through to the end of the bake. It's both fascinating and mysterious to mix final dough flour and water together in a minimal way, to pull on the dough and observe the complete lack of structure, and then to return in 20 short minutes and to see how perceptibly the gluten bonds have developed during the autolyse rest period. Of the many tips and tools that the baker keeps in his or her back pocket, the autolyse technique is one of the most effective.

MIXING GUIDELINES

Different mixers and their mixing times

One of the most common defects in bread is overmixing and the consequent loss of color and flavor. Once the mixer is switched on, the bread's destiny is underway. With few exceptions, moderate mixing in the bowl—as opposed to mixing to maximum gluten development—is preferred. The dough strength that is not developed during mixing can be built into the dough through correct folding during bulk fermentation. It is in fact quite startling to see a dough that leaves the mixer as a weak sticky mass become transformed by something as simple as a few folds into a cohesive, well-structured dough, bearing little resemblance to its former self.

When bread dough is mixed slowly, on first speed only, little physical dough strength is developed by the mechanical action of the mixer. This lack of strength is compensated for by a lengthy bulk fermentation (the acidity produced during the fermentation strengthens the dough) and a few folds along the way. On the other hand, when dough is mixed intensively on high speed until the gluten is developed to its maximum, the dough is so highly developed at the end of the mix that it will not support a lengthy bulk fermentation. The dough has become overoxidized, and the fragile carotenoid pigments have been mixed to oblivion. In this case, the bread will come out of the oven sooner, but at the inevitable expense of flavor, texture, and keeping quality. For most breads then, the preferred method is the middle ground: moderate gluten development in the bowl, and folding as needed to increase dough strength.

It is hard to generalize about mixing times, because there are so many factors that affect them. Some breads are made with sourdough or some other pre-ferment, some are high in butter and eggs, others are made with soaked grains, and all these factors affect mixing time. Further, on some mixers the bowl turns, while on others it does not. One useful guideline is knowing how many revolutions a dough hook makes per minute in each speed, and then to mix doughs to a certain total number of revolutions. Generally speaking, moderate gluten development can be accomplished by mixing to about 900 to 1,000 revolutions (doughs high in rye flour, those like brioche that are high in butter, and those that are intentionally mixed only lightly on first speed have different needs, which are detailed in the individual formulas). The following chart gives approximate mixing times to achieve 900 to 1,000 revolutions for four styles of mixers, including home-style stand mixers. Note that revolutions per minute vary not only between different mixer styles, but also between different manufacturers' models of the same type mixer. Make a call, write a letter, but somehow—know your rpms!

For better or worse, it is true that if you mix the same dough four times, once each using one of the four different-style mixers, four different doughs would result. In other words, even if the dough is mixed to about 1,000 revolutions total, the mixing arms of the different mixers have a different action and a different effect on the dough. A stand-type mixer in particular has difficulty developing the strength of the dough, and while 3 minutes on first and 3 minutes on second speed is usually sufficient with a spiral mixer, in a stand mixer the dough will be comparatively undermixed at that point, and more second-speed mixing will be required. Without a doubt, the length of mix time is very important, but you should always factor in the feel of the dough and its degree of gluten development when mixing.

MIXER	FIRST-SPEED MIXING	SECOND-SPEED MIXING
SPIRAL	3 minutes	3 to 3½ minutes
PLANETARY	3 minutes	4½ to 6 minutes
OBLIQUE	5 minutes	8½ to 10 minutes
STAND MIXER (such as a KitchenAid-type mixer)	2½ minutes	5 to 7 minutes

gluten development actually takes place more quickly when there is less dough in the bowl, because a greater proportion of the overall dough is worked with each revolution of the mixing arm compared to larger doughs.

Hydration. Hydration is the percentage of water in a dough relative to the flour. Wet dough, dry dough—which develops more quickly? As a rule, firmer doughs develop more quickly than looser ones. As the percentage of water increases, the dough hook moves through the dough with less resistance, which in turn results in less-rapid development of the gluten network. This reduction in resistance also means that less friction is generated, compared to that of a firmer dough mixed for the same length of time. And last, we should also note here that oxidation of carotenoids occurs less rapidly in wetter doughs, hence wet doughs can be mixed longer without losing the aroma and flavor associated with carotenoids.

The types of flours in the dough. Rye flour has little of the structure-forming properties of wheat flour, and you can mix it all day and not approach the kind of physical gluten development typical of wheat flour. In fact, mixing requirements are quite different with rye (they are discussed in depth beginning on page 210). When mixing whole-wheat bread, the comparatively coarse and sharp particles of the wheat tend to have a puncturing effect on the gluten network, which in turn necessitates somewhat longer mixing for dough development. White flours have their own considerations. A high-gluten white flour will require more mix time than a white flour with a lower gluten content, because it simply takes longer to develop the gluten in high-gluten flour. Soft wheat flours, such as pastry flour, barely develop at all, and once they do, are often subject to quick breakdown if overmixed. While there are some effective methods for improving the performance of poor flour (for example, a higher percentage of pre-ferment, more folds, or longer bulk fermentation), careful and appropriate flour choice at the outset is always recommended.

The presence of other ingredients. When fats are added in the form of butter, oil, eggs, and so on, the lipids coat the gluten strands and delay their development. As fat content increases, so too does the mixing time required to develop the dough. It is for this reason that doughs such as brioche, which typically have from 40 percent to as much as 70 percent butter in relation to flour, are fully mixed before the butter is added. Sugar also softens gluten structure, and as the sugar content in a dough increases, so too does necessary mixing time. Last, when seeds or grains, either toasted, raw, or in the form of a soaker, are added to dough, they will have a puncturing effect on the gluten, and therefore the dough will require more mixing.

STEP THREE: BULK (PRIMARY) FERMENTATION

As soon as the mixer is turned off, dough fermentation begins. Whatever oxygen is in the dough at the end of mixing is consumed within minutes by the yeast, and fermentation proceeds in an anaerobic state, that is, in the absence of oxygen. As a rule, fermentation is initiated either by the use of a natural leaven, elaborated from a sourdough culture that the baker maintains, and added to the dough at the time of mixing in order to generate the fermentation; the use of a yeast-generated pre-ferment such as a poolish, biga, or *pâte fermentée;* the addition of commercial baker's yeast to the dough; or the combined use of two or more of these. It is during primary fermentation that the majority of the dough's flavor develops. (Needless to say, artificially speeding up this phase by using dough conditioners, powdered sourdough, or no-time dough mixes will have consequences that emphatically detract from bread quality.) Breads with a high percentage of rye flour are the exception; in these doughs, bulk fermentation tends to be comparatively short, and a great deal of the bread's flavor comes from the ripe sourdough.

Of great importance for the development of bread flavor is the production of organic acids during fermentation. Not only do these organic acids contribute significantly to bread flavor, but they also have a strengthening effect on dough structure and therefore are a major contributor to dough development. Organic acids also improve the keeping quality of baked loaves. Since the organic acids develop quite slowly—it takes hours before they are sufficiently present to benefit bread flavor—the use of pre-ferments, which mature over the span of many hours and are replete with developed organic acids, is a highly effective way of augmenting bread flavor. Another result of dough fermentation is the production of carbon dioxide, a by-product of the yeast's activity. Some of the carbon dioxide exists in a gaseous form in the dough and some is present in a dissolved state in the liquid portion of the dough, where it remains until the bread temperature rises during baking, at which point it becomes gaseous, expands, contributes to oven spring, and eventually dissipates.

While fermentation can occur at temperatures anywhere from 30° to 130°F (−1° to 54°C), there is an optimum range. For wheat-based breads, the range is generally between 75° and 78°F (24° and 25°C), while for rye breads it is 5°F higher (about 3°C) at least. From the narrow perspective of yeast activity and gas production, maximum activity occurs at temperatures somewhat higher—over 80°F (26°C), in fact. However, gas production is not the only goal: Flavor development must also be considered, and generally speaking the flavor components in the dough prefer temperatures lower than that required for maximum gas production. For wheat breads the 75° to 78°F (24° to 25°C) range encourages both flavor and volume to develop in a balanced fashion, without favoring one characteristic at the expense of the other.

STEP FOUR: FOLDING

Until quite recently, most American bakers were taught to punch down the dough once or twice while it rose. While this accomplished an important need, it was at best only partially effective. Folding the dough, as opposed to punching it down, is much more effective, and is, in fact, a baker's technique that is as important as it is overlooked. Proper folding, at the right time, can make the difference between mediocre bread and exceptional bread. Why?

First of all, how to fold: There are a few ways to fold the dough—one is directly on the work bench and the other two are in the dough bucket. For the bench fold, first flour the work surface, using somewhat more flour than you think is necessary. Excess flour will not be incorporated into the dough because it will all be brushed off. If there is a lack of flour on the work surface, the dough will stick to it as it is folded, with an

THE STAGES OF FERMENTATION

THERE ARE FOUR DISTINCT, INTERCONNECTED STAGES of fermentation in bread doughs, with a fifth that is common. Bulk (or primary) fermentation is the first stage, and it begins the moment the mixer is turned off. The dough may be folded once, twice, or even three times before dividing, but these all take place within the bulk fermentation phase. After dividing and preshaping, the second phase of fermentation begins: bench rest. Once the loaves are shaped, the third phase, known as final proofing or fermentation, begins. The final phase takes place once the dough is loaded into the oven. This phase, which contributes to the initial burst of oven spring, is brief as yeast activity decreases rapidly above 95°F (35°C). Although there is virtually no yeast activity above 116°F (47°C), it is not until about 138°F (59°C) that the yeast dies completely. Once this "thermal death point" is reached, all fermentation ceases. An optional phase of fermentation takes place when pre-ferments are used. The hours of yeast activity that occur as the pre-ferment ripens are a distinct phase of fermentation.

The Stages of Fermentation

PRE-FERMENT	Bulk (Primary) Fermentation		Bench Rest	Final Fermentation	Oven Spring	138°F
(optional)	Fold	Fold				

accompanying ripping of the dough's surface. This, needless to say, is not a desirable sight. Next, turn the dough out onto the work surface, so that the top of the dough is neatly turned over and spread onto the floured work surface. Now take one side, say, the left side of the dough, and lift up about one-third of the bulk and turn it vigorously onto the body of the dough. With spread fingers, use both hands to pat down the dough and degas it. Don't attempt to drive out every bit of fermentation gas; just press enough to expel the major portion of the gases. Now take about one-third of the dough from the right side and fold it in toward the center, overlapping the first fold. Again press to degas. Be sure, before that second folding and prior to all folds, that any raw flour on the top surface of the dough is brushed away. Make every effort to avoid incorporating raw flour into the dough; otherwise, gray streaks will show in the baked loaf, and the seam of baked raw flour will give a bad visual as well as eating impression. After folding the right-hand third of the dough into the center, reach over to the far side of the dough, bring about one-third toward you, and fold this portion. Finish by taking the dough closest to you and folding that portion away from you and into the center. When this fourth side has been folded, turn the dough over on the work surface so the seams are underneath, bring your arms under the dough from the left and right sides, pick it up in a mass, and replace it in the dough container. It is not unusual or particularly difficult to fold a container of 50, 60, or even 70 pounds (about 22 to 30 kg) of dough; it can, however, be a bit tricky to transfer the dough back to the container when it gets much heavier than that; in this case, a second person is helpful, or you can simply use more containers with less dough in each.

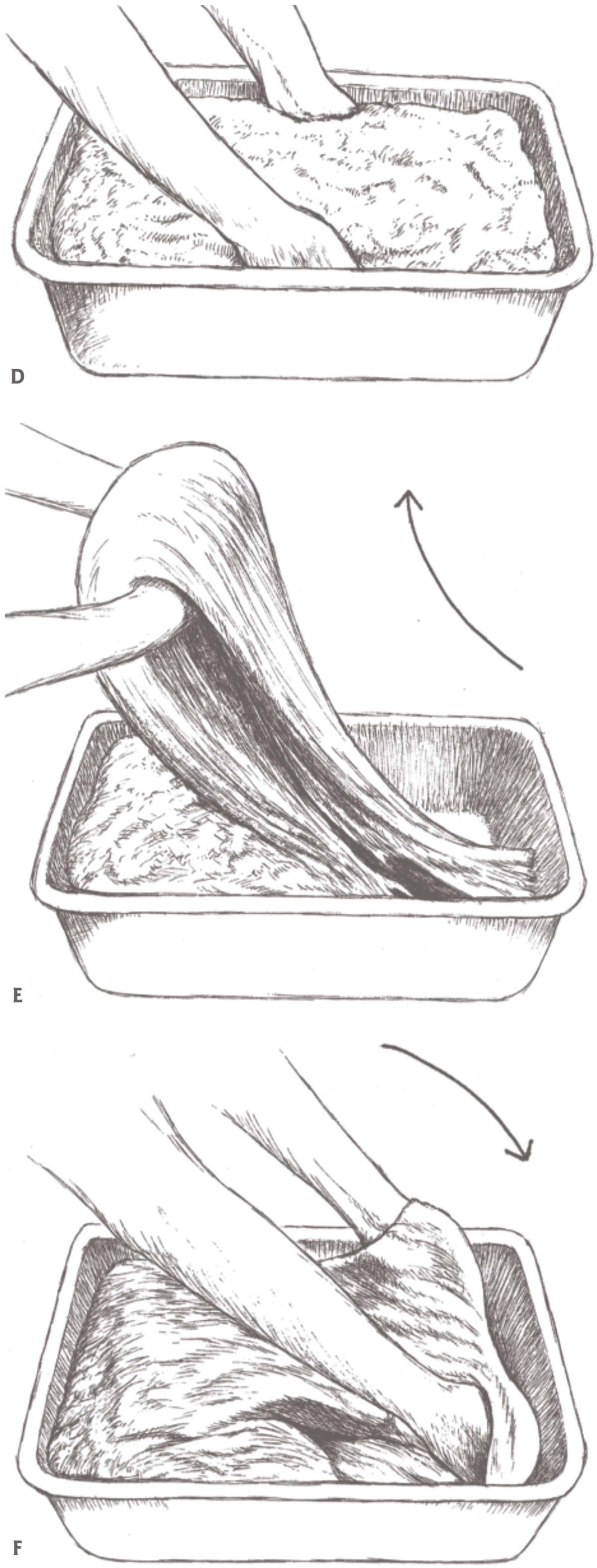
An alternative to the folding method described above is known as bucket folding. Bucket folding is easy, quick, and efficient. It works well with all kinds of dough—loose or firm, lightly or fully fermented. It has the further advantage of not requiring heavy dough tubs to be lifted onto the bench. It's easiest to bucket fold with wet hands (the water acts as a lubricant and less dough will stick to you), so have a container with water close by. For the first method, plunge both hands into the container, then grab the dough at one end of the dough tub (see Illustration A). Reach down to the bottom of the tub, lift the dough high, and fold it over the main body of the dough (Illustration B). Remoisten your hands, if necessary, and repeat with the dough at the other end of the tub. Repeat these steps with the other two portions of dough, so that you eventually have folded the north, south, east, and west portions of the dough (Illustration C shows the beginning of the folding of the second portion). Once finished, there is no need to turn the dough over.

A

B

Bucket folding

The second bucket folding method has similar results as the bench method, as when it is finished, the dough orientation remains as it was before the folding, with seams on the bottom. Because it incorporates a fair amount of air, there is an indication that it also has a positive effect on overall dough fermentation. Buckets must be oiled for this method in order for the dough to release easily from the bucket. Here's how to do it: Position the bucket so the short dimension is facing you. With moistened hands, reach down the sides of the dough, a little more than halfway towards the far end of the bucket, as in Illustration D. Lift the dough up from the bottom, angling it slightly back toward you, as in Illustration E. Once it is released from the bottom, in one smooth motion pull the dough toward you and fold it back over on itself away from you, as in Illustration F. Repeat this one or two times more, until this entire segment of the dough has been lifted and folded. Turn the bucket around 180 degrees so that the remaining unfolded portion of the dough is away from you and repeat. When finished, the top surface will be taut, and the dough will be smooth, cohesive, and perceptibly stronger.



Second bucket folding

Once the dough has been folded (by the first method and the second bucket methods), there is a top portion that is seamless and smooth, more or less the outer surface skin of the dough. And there is also an underside where the seams from the folding action come together. From the time of the first fold throughout the rest of the dough's journey to baked bread, the smooth top and seamed bottom remain in the same orientation. If there are further folds, the top remains the top and the bottom the bottom; when the dough is divided and preshaped, the orientation continues, as it does once the dough is shaped. Think of the dough—both in bulk and then when divided into individual loaves—as having an axis, not unlike the North and South Poles of that giant round loaf we all live on.

By folding the dough correctly, we accomplish three important things. First, we degas the dough. If the excess of carbon dioxide gas that is generated by the yeast is not periodically expelled, fermentation can be impaired. The degassing function can in fact be achieved by the old "punching down" method; however, it is more effective when the dough is folded, and other benefits are derived as well. A second benefit is the equalization of dough temperature. Although this is not always a factor, it can be helpful. If we have a cool dough in a warm room, the outside of the dough warms more rapidly than the inside; by folding, we tend to equalize the temperature by bringing the warmer outside into the center of the dough. Conversely, if we have a warm dough in a cool room, in a similar fashion correct folding helps to equalize the temperature of the dough. A third benefit of correct folding is an increase in dough strength, and this can have an enormous impact on the dough. When we fold the dough, the gluten strands are again being stretched and aligned, and we instantly feel a dramatic strengthening of the dough.

WHEN TO FOLD

The third consideration when we discuss folding is when to fold, and this is the most complex aspect of the three. As we have seen, in order to preserve the flavor components of the dough and to avoid overoxidizing it, we intentionally mix to less than full gluten development. We make up for this slight undermixing by folding correctly and thereby increasing dough strength. But how often should a dough be folded? This depends on the type of dough, its desired strength, and the length of fermentation prior to dividing. Here are some considerations:

- **DOUGHS (PARTICULARLY THOSE MADE WITH BAKER'S YEAST)** that ferment for more than about 1½ hours should receive at least one fold if for no other reason than to degas them.
- **DOUGHS MADE WITH A HIGH PERCENTAGE OF PRE-FERMENTED FLOUR** (35 percent or more) tend to have good strength (because of the strength-inducing properties of the acids that develop in the pre-fermented flour), and too many folds can be detrimental to the finished bread. If an excess of strength is built into the dough, extensibility suffers, and the too-strong dough will have difficulty achieving a full rise in the oven. This is directly counter to the notion that the only thing that matters in flour and dough is protein and strength, but without a doubt when a dough is too strong its expansion is impaired.
- **DOUGHS MADE WITH WEAK FLOUR** benefit from extra folds.
- **DOUGHS WITH A HIGH HYDRATION** benefit from extra folds. Ciabatta dough, with its typically high hydration rates of 75 percent up to even 85 percent, is a great example of the benefits of folding. As more folds are incorporated, the resulting breads are progressively more voluminous.
- **DOUGHS WITH A SHORT BULK FERMENTATION**, such as sourdough rye breads, do not require any folding, nor do they benefit from it, since there is no glutenin, and dough structure will not be improved by folding.
- **DOUGHS THAT ARE BY NATURE STIFF**, such as challah, do not require folding, since they tend to have adequate dough strength at the completion of mixing. Thorough degassing may be indicated, however, when bulk fermentation is longer than an hour or so.

BENEFITS OF PRE-FERMENTS

A PRE-FERMENT IS MADE by taking a portion of a bread dough's overall ingredients, mixing them together, and allowing them to slowly ferment for several hours before mixing the final dough. Typically, pre-ferments ripen between roughly 6 and 18 hours, although there are instances where they ripen for a longer or shorter duration. Although not every type of bread dough requires or necessarily benefits from the presence of a pre-ferment, the correct use of pre-ferments has important benefits, which result from the gradual, slow fermentation that occurs during the maturing of the pre-ferment. Chapters 4 through 6 contain a thorough examination of the major pre-ferments and their individual characteristics. In this section we will take a quick glance at the main benefits derived from their use:

- **DOUGH STRUCTURE IS STRENGTHENED.** A characteristic of all pre-ferments is the development of acidity as a result of fermentation activity, and this acidity has a strengthening effect on the gluten structure.
- **BREADS DEVELOP A SUPERIOR FLAVOR.** Breads made with pre-ferments tend to possess a subtle wheaty aroma (or a robust rye flavor, as the case may be), delicate flavor, a pleasing aromatic tang, and a long finish. Organic acids and esters (aromatic compounds produced by the yeast) are a natural product of pre-ferments, and they contribute to superior bread flavor. While it is true that there are some exceptional breads that do not use pre-ferments, in the overall panoply of breads, those made with pre-ferments possess the most enhanced flavors.
- **KEEPING QUALITY IMPROVES.** There is a relationship between a bread's acidity and its keeping quality. As the pH of a bread decreases (that is, as acidity increases), there is a concomitant increase in the keeping quality of the bread. Historically, Europeans, particularly those in rural areas, baked once every two, three, or even four weeks. The only breads that could keep that long were breads with high acidity, that is, levain or sourdough breads.
- **OVERALL PRODUCTION TIME IS REDUCED.** Above all, to attain the best bread we must allow sufficient time for its development. Straight dough that is mixed and 2 or 3 hours later is in the oven will always lack character when compared with bread that contains a well-developed pre-ferment. By taking 5 or 10 minutes today to scale and mix a sourdough, a poolish, or some other pre-ferment, we significantly reduce the length of the bulk fermentation time required tomorrow. The ripe pre-ferment immediately incorporates acidity and organic acids into the final dough, serving to reduce required bulk fermentation time after mixing. As a result, the baker can bring bread from the mixer to the oven in substantially less time than when making a long-fermented straight dough.

STEP FIVE: DIVIDING

Bulk fermentation ends when the dough is divided. Mechanical dividers that cut 20 or so pieces in just a few seconds are common in production bakeries, and they are of course much quicker than hand dividing. That said, there is something really pleasing about the hand and eye coordination inherent in hand dividing, and the steady rhythm it entails. A metal dough cutter, a scale, and good hands are all that are necessary to perform the task. Speed is important, particularly when dividing dozens of pieces at once, in order to avoid overaging the dough. Frequently dusting the plate of the scale and the hands with flour keeps things dry, and the work goes quickly and smoothly. If the dough sticks to either the hand or the scale, speed suffers, and so does the surface of the dough, which in all likelihood will rip. Once a dough piece has been divided at the correct weight, it is helpful to cut successive pieces as close to that size as possible. Small corrections—either adding on or taking off a small piece of dough—are almost always necessary. However, try to avoid having a dough piece that consists of lots of little chunks of dough; one cohesive dough piece is preferable to one made up of numerous small chopped bits.

STEP SIX: PRESHAPING

Once divided, the dough is preshaped in order to change the randomly shaped pieces into more consistent shapes. Preshaping organizes the dough pieces, making final shaping easier and more effective. A light rounding suffices for most breads, but it's worth noting that a strong preshaping can be a good tool to bring an extra dose of strength to weak doughs. However gently or firmly the preshaping, final shaping must wait until the dough has sufficiently relaxed. Since the tightness to which a loaf is preshaped determines when the final shaping can occur, the baker can use this to his or her advantage. For example, if, because of other aspects of the production schedule, the bread needs final shaping in a relatively short time, a light preshaping is sufficient; if, on the other hand, other doughs must be divided, mixed, or loaded into the oven before the preshaped dough gets its final shaping, then a tighter preshaping is indicated, since the dough will require more time to relax before final shaping.

Preshaped loaves should be placed on a floured work surface or floured bread boards. Lay the dough pieces down sequentially, with the same number of pieces in each row. It is then an easy matter to calculate the dough yield (it is easier to calculate 10 rows with 6 loaves in each row than it is to count 60 individual pieces of dough). Further, an orderly placement of the dough means that the loaves receive final shaping in the order in which they were preshaped, so their length of bench rest will be similar.

Some bakers place the preshaped loaves onto the work surface with the seams down, while others put the good side down and the seam side up. Although it isn't exactly a raging controversy, it's worth discussing the two approaches. Those who place the seams down do so in order to keep the dough more concise, and it's true that a preshaped loaf will hold its shape better when the seams are underneath; when the seams are on top, they tend to spread somewhat. I have never found the slight spreading of the seams to be a problem, and prefer placing the good side down. Here is my reasoning: In a typical situation, I work with hundreds of loaves each day—that's a fair bit of dividing, preshaping, and shaping. Flour is spread onto the work surface prior to receiving the preshaped loaves, and in fact sometimes it is a little on the light side, sometimes a little on the heavy side. By keeping the seams up and the good side down, I avoid any incorporation of raw flour into the loaf, because none of the work surface flour becomes incorporated into the dough during shaping.

STEP SEVEN: BENCH REST

This passive step is for the dough, not the baker. The baker has many more hours to go before it's time for rest. The preshaped loaves are covered with a sheet of plastic to prevent a surface crust from forming, or vinyl covers are zipped down if the bread rests on wooden bread boards in rolling racks. As mentioned above, the duration of bench rest is directly determined by how loosely or tightly the loaves have been preshaped.

STEP EIGHT: SHAPING

Round or *boule*-shaped loaves, oval- or *bâtard*-shaped loaves, baguette-shaped loaves, and some of the less common shapes, such as *fendu* loaves where the dough is impressed with a rolling pin, triangular shaped loaves, and all the variations on the shaping theme, proceed toward their destiny as the baker takes the preshaped loaves and gives them a final shaping (the specifics of how to make some of the various shapes are detailed beginning on page 54). Once shaped, the loaves go into *bannetons* or between folds of baker's linen, or into metal loaf pans or onto sheet pans. Once again, they are covered to prevent dehydration of the surface. Temperature- and humidity-controlled environments, such as retarder-proofers, are excellent for this purpose, but lacking that, choosing an area in the bakery or home that is either warmer or cooler as appropriate, and covering the loaves with baker's linen and plastic, is adequate.

STEP NINE: FINAL FERMENTATION

Final fermentation (final proofing) is the phase between shaping and loading the loaves into the oven. While bread flavor is largely determined by the correct mixing technique, the use of a pre-ferment if appropriate, the duration of the bulk fermentation, and the quality of the bake, the major goal of the final fermentation is to raise the bread to the desired degree. If the bread is either overrisen or underrisen, the eventual eating quality, as well as its visual aspect, will suffer. As a rule, bread should not be 100 percent risen at the time of the bake. Just as we will fall onto our noses if we lean over 100 percent, so too will the loaves collapse if they receive a full 100 percent proofing before the bake. It is difficult to quantify with unvarying certainty the perfect degree of rise, since there are so

THE WORKMANSHIP OF RISK AND THE WORKMANSHIP OF CERTAINTY

IN THE REMARKABLE BOOK, *The Nature and Art of Workmanship*, English furniture maker David Pye discusses what he terms "the workmanship of risk and the workmanship of certainty." He also offers a definition of that elusive word "craftsmanship," which gets to the heart of the term with no wasted verbiage: "If I must ascribe a meaning to the word craftsmanship, I shall say as a first approximation that it means simply workmanship using any kind of technique or apparatus, in which the quality of the result is not predetermined, but depends on the judgment, dexterity, and care which the maker exercises as he works. The essential idea is that the quality of the result is continually at risk during the process of making; and so I shall call this kind of workmanship 'The workmanship of risk.'" These concepts are as applicable to the baker (particularly these days when the term "artisan" is bandied about in search of a clear definition) as they are to a furniture maker such as Mr. Pye, and to the practitioners of all handcrafts. As bakers, we face risk every day. On a humid day the dough may feel a little slack, and with no conscious cerebral effort, we adjust our hands and our connection to this particular dough. Does a machine do that? When working with local grains, we may find that the dough is a bit weak. We make unconscious adjustments in our shaping to bring the maximum strength to the dough without tearing it. Can a machine do that? I'm not opposed to the use of mechanical processing equipment, and realize it is inevitable for bakeries of a certain size to utilize it—how else to increase production quantity, speed, and efficiency? What I am opposed to is the de-skilling of bakers, and if all our breads are mixed, divided, and shaped by machines (and oftentimes mechanically slashed and loaded into the oven as well), how many of the traditional bakers' skills remain for us to practice? One of the great joys of my work life is standing at the shaping bench with two or three of my co-workers, all of us shaping with a steady rhythm, chatting and laughing, working well and quickly, but not in a frantic or stressed way. I am so glad and grateful that our daily production is such that we don't need to resort to machines to shape our breads. Yes, machines are fast, but not so interesting to talk to.

many variables involved; however, 85 to 90 percent rising is a fair approximation to begin with. With careful and consistent observation of each bread, the baker's eyes and hands will soon learn the parameters that work best.

STEP TEN: SCORING

Some breads, like braided loaves, ciabattas, *fendu*-shaped loaves, and some pan loaves, go into the oven with no scoring. Other breads, however, are scored with a razor or other blade before baking. By scoring the bread, we intentionally create a weak section on the surface of the loaf in order to encourage a controlled expansion of the bread. Left unscored, bread has difficulty expanding to its fullness; it will burst out through any weak spots on the surface and generally will have a distorted and tortured shape. Breads like baguettes have a traditional scoring that rarely varies; other breads are scored in an infinite variety of ways, which not only give a certain distinctiveness to their appearance, but also, in a sense, become the signature of the baker.

There are, of course, no rules that dictate how to score bread. Experimentation will soon show how great an impact different scoring methods have on different breads. If a bread is weak, either from overrising or due to its nature (for example, breads with a high proportion of rye flour), light scoring is indicated: Since the lateral structure of the loaf is already somewhat compromised, deep scoring makes the bread tend to flatten out rather than rise upward. On the other hand, breads that have good strength and are at the optimum degree of rising at the time of the bake can handle more vigorous scoring, and their cuts will expand beautifully in the oven.

STEP ELEVEN: BAKING

It's unlikely that the stalk of wheat, inclining sunward, bathed with breezes and light (and ravenous bugs and withering fungi and pummeling hail and rain), is merrily awaiting the day it will become a loaf of bread. And yet I can't help but regard the baked loaf as the ultimate fulfillment of a grain's long journey from the field to the oven. So much of human culture, civilization, and history are interwoven with the story of grain, for so many centuries humans have relied (often almost solely) on grain for their sustenance, and so much of the labor of lives has been directed toward the raising, procuring, and transforming of grain into edible nourishment that it is difficult to imagine life as we know it without this food. It is true that there are rice cultures and corn cultures and manioc cultures, but wheat and rye culture runs as deep or deeper than any in the physical and psychic realms of humans. In any event, leaving aside culture, myth, and even the bare needs of sustenance, it is only when the baker has consigned his or her loaves to the vagaries of the oven that the final transformation occurs—behold, the baked loaf.

Generally, bread dough is in the 70° to 80°F (21° to 26°C) range at the time of loading into the oven, and when it enters the hot of breath of the oven, it undergoes enormous physical, biological, and enzymatic changes. The first visible change to the observer is the dramatic phenomenon known as "oven spring," the last phase of fermentation. Carbon dioxide is produced by the yeast throughout the entire duration of dough fermentation. As the dough begins to heat up, fermentation speeds up and the production of carbon dioxide increases. This burst of oven spring doesn't last long however, as yeast activity drops off dramatically above 95°F (35°C). A more pronounced phase of oven spring occurs as the carbon dioxide, which has been dissolved in the liquid portion of the dough, converts to a gaseous state and expands as the dough continues to heat. Enzymes are highly active at this early stage, particularly on the surface of the dough, where they convert starches into sugarlike compounds called dextrins, which will contribute to crust coloration later in the bake. Bacteria die when the internal dough temperature reaches about 122°F (50°C); also at about that temperature, the starch in rye flour begins to gelatinize (the potentially disastrous consequences—the starch attack—are described on pages 38 and 39).

During the outset of the baking process, the flour starches absorb water, swell, and become glossy (when bread dough is mixed, only the outer surface of the starch

TEMPERATURE INFLUENCES ON BREAD AS IT BAKES	
77° to 122°F (25° to 50°C)	Rapid increase in yeast fermentation; increase in enzymatic activity; beginning of crust formation; starch swelling; accelerated gas production and expansion contributing to oven spring.
122° to 140°F (50° to 60°C)	Rye starch begins to gelatinize; bacteria die; enzymes in yeast are inactivated; yeast reaches "thermal death point" (at about 140°F or 60°C).
140° to 158°F (60° to 70°C)	Wheat starch begins to gelatinize; loaf expansion slows; coagulation of gluten begins; amylase enzymes reach maximum activity.
158° to 176°F (70° to 80°C)	Gluten coagulation is complete and dough structure is formed; enzyme activity decreases; rye starch gelatinization ends.
176° to 194°F (80° to 90°C)	Wheat starch gelatinization is complete; enzyme activity ceases.
194° to 212°F (90° to 100°C)	Maximum internal loaf temperature is reached; crust coloration begins.
212° to 350°F (100° to 177°C)	Maillard reaction develops crust color; ketones and aldehydes form, eventually contributing to flavor and aroma.
300° to 400°F (149° to 204°C)	Further crust color and flavor development through caramelization.

BAKING AND THE FIVE SENSES

THERE IS A LOT TO BE SAID for learning the technical aspects of bread baking, and in no way do I mean to diminish them. As we learn the academics of bread, we become better bakers: more knowledgeable, more consistent, more confident. But bread baking is about much more than just academic information—it is a pursuit that truly involves all the senses.

- **HEARING.** As the dough spins in the mixer, the sound changes, and as it begins to develop we hear a slap, slap, slap against the side of the bowl, a popping sound as the dough strengthens. Train yourself to listen for those sounds; they are guides to the way the mixing dough is developing.

- **TOUCHING.** So much of baking is about the sense of touch. We feel the dough as it mixes, in order to learn to understand in a tactile sense the changes it goes through from the beginning of the mix to the end. Every dough should be squeezed and tugged and examined with the fingers. As the bulk mass of dough rises, feel it; as the shaped loaves are rising, feel them—we slowly train ourselves to understand what is happening *inside* the dough simply by feeling the *outside* of the dough. How do we know when the bread is sufficiently baked? Until quite recently, no one plunged a thermometer into the nether regions of the bread. Ascertaining doneness has always been a function of touch. Just by giving the bread a good squeeze and a thump on its bottom, your fingers gradually gain the knowledge of "doneness."

- **SMELLING.** The sense of smell is crucial! Smell the poolish or sourdough, inhaling deeply—is it wheaty and ripe, with a nice sweet tang, or bland and weak, stuck in neutral? There is a magic time once the bread is in the oven, when the first faint risings of aroma—almost timid!—waft into the air; and even when you are running around with a dozen things to do, a small smile comes to your face as you breathe in the first fragrances of the baking bread.

- **SEEING.** Our eyes guide us at every stage, from the mix right through to the end of the bake. If "the books" say to let the loaves rise for an hour and a half, but your eyes (in conjunction with your fingers) say the bread is ready to bake after an hour and a quarter—get rid of the book and go with your senses! Our eyes divide the loaf into sections as we glide the *lame* over the dough's surface, helping us to score the bread with symmetry; our eyes guide us in determining doneness—if the bread is still too pale at the base of the cuts, give it another few minutes.

- **TASTING.** There is so much to taste from start to finish. Always taste the sourdough when it is ripe—after all, we want to keep our sourdough healthy and vigorous for years and years, and by tasting it each time it ripens we will know if it is properly matured with a balanced acidity, or if it is showing signs of imbalance and needs some special treatment. Taste the dough as soon as the ingredients have come together—is the salt in there, and is it the correct amount? Roll a bit of the dough around in the front of your mouth once the mix is done—you will slowly learn to pick up the flavor of the pre-ferment in the raw dough. When the bake is done and the bread cool, taste it and taste it again. First with a critical mouth to determine how today's efforts went. But then for the pleasure and fulfillment of eating bread.

Hearing, touching, smelling, seeing, and tasting—bread is about all of these. The bread is always talking to us, and only when we open ourselves fully—mind and senses together—do we slowly begin to learn the subtle, but quite articulate, language of bread.

STEAM

ANYONE WHO BAKES WITH A STEAM-INJECTED OVEN knows the virtues of steam. With the exception of breads that receive an egg wash prior to baking and therefore do not require steam, every bread benefits from steam. Just prior to loading the oven, steam is injected into it so that the loaves enter a moist environment. Once loaded, a second steaming is applied. If the oven's steam injection is effective, approximately 4 to 6 seconds of overall steaming is normally appropriate. It is, unfortunately, quite commonplace to see oversteamed bread (if a little is good, more must be better, and besides, that oven cost $75,000 and I want to get my money's worth from the steam injection); the consequences are flattened loaves with a thick, chewy crust and cuts that don't spring open. If bread is slightly underrisen, a little extra steam ensures that the surface of the loaf remains moist longer, so the bread can rise more. If bread is slightly overrisen, somewhat less steam is necessary, since it is important to have the crust firm more quickly to prevent the bread from flattening out. Proper steaming has a profound effect on bread for a number of reasons: It promotes a rich color to the crust and a surface shine on the loaf, and it also increases the volume of the bread. Let's look at the details of each of these.

Crust color is enhanced when steam is injected into the oven. This is because during the early stages of baking, there is a rapid increase in enzymatic activity on the surface of a loaf. These enzymes break down the starches in the dough into dextrins and other simple sugars called "reducing sugars"; these substances eventually contribute to crust color. Steaming the oven moistens the surface of the dough, and this enables the enzymes to remain active for a longer period of time, yielding richer color. In an unsteamed oven, the surface of the loaf quickly becomes too dry for these enzymes to function, and the resulting bread will have a pale, lusterless crust.

A properly steamed oven promotes a crust with a good sheen to it. This is because steam at the initial stages of baking provides moisture that gelatinizes the starches on the surface of the loaf. The starches swell and become glossy, resulting in a shining crust. In an oven without steam, the crust undergoes a process called pyrolysis. In this case, instead of gelatinizing, the starches and the crust of the bread remain dull.

A properly steamed oven results in bread with better volume. As the bread enters the hot environment of the oven, there is a rapid increase in volume due to oven spring. When we load an oven without steam, the surface of the loaf quickly heats up, and as a crust forms on the surface, oven spring is reduced and the bread's ability to attain further volume is impeded. On the other hand, in a steamed oven, the surface of the dough remains moist longer, enabling greater oven spring to occur before the formation of a surface crust, and the result is bread with superior volume.

The benefits of steam occur only during the first third or so of the baking cycle. If the baker neglects to inject steam at the time of bread loading, he cannot compensate by steaming the oven several minutes later. In order to ensure that the crust remains thin and crisp, it is important to finish the bake in a dry oven. For this reason, the oven should be vented or the doors notched partially open for the last portion of the bake. As a general rule, once the bread begins to show color, the vents can be opened for the duration of the bake. In the home oven, venting is rarely an issue, as for the most part home oven chambers are relatively porous and excess steam is minimal.

When baking naturally leavened breads, that is, breads made with no commercial yeast, the proper steaming technique is slightly different. In order to assure that the breads have the opportunity to reach their optimum rise, it is first necessary to give the oven a full steaming just prior to loading the breads. Once loaded, steam again, slightly longer than you would for a yeast-leavened bread. And once that steam has subsided (perhaps 1 to 2 minutes after the steaming), give the oven one more hit of steam. The effect of the extra steam is to ensure that the loaves remain moist on the surface long enough to rise fully, a process that takes longer with naturally leavened breads than with their commercially yeasted kin. As with any bread, once a surface skin has formed, it is difficult for the loaf to break through to further expansion. Since naturally leavened breads spring more slowly in the oven, the extra steaming delays the formation of the surface skin, and loftier loaves are the result. This technique is especially helpful for naturally leavened breads that have been retarded and enter the oven in a cold condition. Note: The extra steam is not recommended for any breads that are at maximum rise at the time of the load, as they would be susceptible to collapsing, as explained in the first paragraph above.

Even in the home oven, a reasonable amount of steam can be created. First of all, a preheated baking stone of some sort should be used for most bread. As the stone is preheating, a sturdy cast-iron pan with a 10- to 12-inch diameter should be placed in the oven (some bakers put heavy pieces of stainless steel or lava rocks used for grilling into the cast-iron pan; the idea is that the increased surface area augments the quantity of steam). When the oven is good and hot, and the bread ready to load, bring a cup of water to the boil. Next, place your bread on a peel and score it, open the oven door, load the bread onto the stone, pour the boiling water into the superheated cast-iron pan, and shut the oven door right away. Another excellent way to create steam in a home oven is bake in a preheated cast iron dutch oven. In my experience the best ones are those where the lid is also a skillet; the bread can be slid onto this portion and the deeper portion is placed on top. Baked this way, the bread not only self-steams, it also benefits from the proximity to the radiant heat emanating from the cast iron.

granules is moistened; later, under the influence of the heat of the oven, the water is able to penetrate into the granules). As temperatures increase from 140° to 158°F (60° to 70°C), swollen wheat starch granules begin to gelatinize and contribute to the formation of the crumb. Loaf expansion slows down at around 140°F (60°C), at which temperature all the carbon dioxide in the dough has been released. Amylase enzyme activity increases to its maximum during this period. Also at this time (about 145°F or 63°C), the gluten, initially soft and with no firm structure at the time of the load, begins to stretch and expand until, at approximately 167°F (75°C), its coagulation is complete and the loaf structure is set. As internal dough temperatures continue to increase, enzyme activity as well as starch gelatinization slow correspondingly, until, at around 194°F (90°C), they cease.

The crust of the bread is the only part of the loaf that exceeds 212°F (100°C); the internal temperature of baked bread reaches a maximum of about 210°F (99°C). When surface dough temperatures reach 212°F (100°C), crust formation and coloration begin, due to the process known as the Maillard reaction, a complex chemical change that causes a rich browning of the bread's crust (or the surface of a grilled steak) and contributes significantly to the flavor of baked bread. The Maillard reaction occurs in the presence of heat, moisture, protein, and reducing sugars, all of which coexist when properly made bread is loaded and steamed. Substances called aldehydes and ketones are formed in this temperature range, and they too contribute to the aroma and flavor of baked bread. At surface temperatures of approximately 350°F (177°C), the Maillard reaction is complete. A further contributor to crust color and flavor is caramelization, which occurs at temperatures between 300° and 400°F (149° and 204°C).

HOW TO BECOME A GOOD FRIEND TO GOOD BREAD

FIRST, LEARN THE BASICS—good mixing techniques, proper fermentations, and skillful baking. How do you learn these? By repetition and attentiveness. Make sure patience is part of your ingredient list.

For all the many parts of baking that require your hands, dedicate yourself to focusing all your attention when mixing, folding, dividing, shaping, and scoring. The hands have an astonishing capacity for memory; when your baking is no longer primarily a cerebral act but more of a tactile one, you have arrived at a place of experience and skill.

Learn to make the classic breads—rye breads, white breads, whole grain breads, enriched breads—they are classics for a good reason.

With time and practice, and a measure of patience, you will learn all you need to. And then your experience can speak to your imagination, and you will develop new breads that suit your personal tastes. Experiment, play, realize that failure isn't really failure, it's an edible part of your evolution as a baker. No two bakes will ever be exactly identical, nor need they be; if they were the same time and time again, wouldn't the bread-making process sooner or later become boring? As the jam and preserve expert Christine Ferber said in her book *Mes Confitures, "Une confiture est toujours une création!"* (A batch of preserves is always a creation!) Spoken like a true bread baker.

MOISTURE LOSS IN BAKED BREAD

A baked loaf never weighs as much as an unbaked one. The water evaporation in dough can be as much as 25 percent or more. Some of the various factors that affect the amount of moisture loss in baked bread are:

- **LOAF WEIGHT.** Larger pieces tend to lose a lower proportion of their initial weight.
- **DOUGH SHAPE AND CRUST-TO-CRUMB RATIO.** Long, skinny loaves such as baguettes are characterized by a high crust-to-crumb ratio, and lose a considerably higher percentage of moisture than the same dough weight shaped into a round or oblong loaf. Pan breads have less evaporation than hearth-baked loaves of the same weight.
- **LENGTH OF BAKE.** There will obviously be a greater weight loss the longer bread bakes. A full bake yields a richer bread flavor, a fact too often underestimated.
- **HEAT.** A hotter oven will bake bread more quickly, and overall evaporation and weight loss will be less than if the same dough weight and shape were baked in a lower oven.
- **TYPE OF OVEN.** Wood-burning ovens, steam-injected deck ovens, rotary rack ovens, and unsteamed pizza-style ovens can each affect the rate of moisture evaporation, although the heat of the baking chamber, the size and shape of the loaves, and the degree of baking combine to have more of an impact than the type of oven used.

STEP TWELVE: COOLING

In a technical sense, a loaf of bread begins to stale the moment it is removed from the oven. This is true, as it is also true that we humans and other living creatures begin to die the moment we are born. In fact, the quality of a loaf is never at its best when first pulled from the oven. While really bad bread may only be palatable when eaten warm (if at all), well-made breads never possess their finest aroma or flavor until they have cooled completely. While warm, the crumb remains doughy and the aroma flat. Some types of breads, for instance sourdough breads, don't come into their own until they have had a few hours or more for their flavors to settle and mingle after cooling. In the case of rye breads made with a high proportion of rye flour, 24 to 48 hours of resting after the bake is necessary for the crumb to stabilize and full flavor to develop. The crumb then loses its threat of gumminess and the flavors meld and mingle beautifully. The eating quality can increase for days.

OLD BREAD

I WAS IN THE MIDST OF A WEEK OF TEACHING a professional bread class at King Arthur Flour's Baking Education Center, when I had an unexpected visit from a dear friend, the great Austrian baker, pastry chef, and chocolatier Markus Färbinger. As we chatted, he kept taking chunks from a loaf of sourdough that had been cut for evaluation purposes quite some time earlier. "Markus," I said. "Let me get you another loaf; that one is way too hard." Markus looked up from his munching, his eyes half amused and half admonishing. "Old bread isn't hard," he said. "No bread is hard."

DELAYING STALING

There is, somehow, a distinction between old bread and stale bread. Old bread (well made) can, like old people, improve in character. The wonderful crust of the fresh loaf may be gone, but there is a subtle complexity that accompanies the bread as the days go by. Nevertheless, bread does eventually age and deteriorate. This process of staling is called "starch retrogradation." Prior to baking, starch is in a crystalline state; during baking, the starch gelatinizes as it swells with water. As the baked bread begins to cool, the starch begins to revert to its former crystalline structure and the crumb of the bread hardens. While eventual retrogradation and staling cannot be eliminated, there are ways to prolong the onset and somewhat delay the effects:

- **COOL THE LOAVES CAREFULLY AFTER BAKING**. Air currents on bread hasten the evaporation of moisture from the crumb and cause a premature crust to form on the surface of the loaf (in humid environments, some airflow can help to pull moisture away from the loaves, helping the crust to remain crisp).
- **BAKED BREADS WILL STALE MOST QUICKLY** at temperatures between 32° and 50°F (0° and 10°C). Clearly, the worst environment for bread is in the refrigerator.
- **WHEN COOLED BREAD IS WRAPPED TIGHTLY** in plastic and frozen to 0°F (−18°C) or lower (particularly if the freezing is done very rapidly), the rate of staling is slowed. However, the bread then goes through the danger zone of 32° to 50°F twice (0° to 10°C)—once as it cools, and again as it is thawed. Even in the best of freezers and with the best possible wrapping, long, skinny loaves like baguettes tend to dry out after a few days; larger round or oblong loaves will keep longer, as will breads that contain a portion of fat.
- **ONE OF THE GREAT BENEFITS OF USING PRE-FERMENTS** or having a long bulk fermentation is that the organic acids developed in the pre-ferment phase or during the lengthy fermentation assist in lengthening the shelf life of bread. The appropriate use of pre-ferments can always be recommended as a way to, among other benefits, add some hours to the fresh life of bread. It is fairly common to read that adding sugar is a good way to extend a bread's shelf life. Although this is technically true, it can rarely if ever be considered an intelligent or skillful way to accomplish that goal. The addition of sugar may increase shelf life, but texture and flavor will certainly be compromised in breads that do not ordinarily contain sugar.
- **STALE BREAD CAN REGAIN SOME OF ITS FORMER EATING QUALITY** if reheated right to the core, which allows the starches to once again gelatinize and the loaf to take on some of its former characteristics. However, it quickly reverts to stale, and should be eaten soon after reheating.

TASTING BREAD

IT MIGHT SEEM ODD to think in terms of learning how to taste bread, but I confess that for years I did not eat bread with an eye toward critical assessment. True, we don't want to sanitize or negate the wonderful pleasure of savoring a slice of well-made bread by confining it to "objective" criteria in an attempt to critically evaluate it. On the other hand, the baker must have standards of judgment, and must be able to appraise the relative merits of today's bread, if for no other reason than to be able to compare it with the breads of yesterday and tomorrow. One of the more alluring aspects of bread baking is the very fact of its variability: The same amount of flour, water, salt, and yeast that made bread today can make a bread with subtle but perceptible differences tomorrow. In fact, sometimes the results one day are sublime, and the next day disastrous. The baker keeps returning to the bench, ever striving to redeem the mistakes of yesterday, ever seeking to improve the bread.

In any case, developing a language to assess our products allows us to monitor our daily efforts, which in turn can be beneficial in achieving breads that stay within certain quality parameters. Where do we begin? In 1996, I was chosen as one of three Americans to represent the United States in the Coupe du Monde de la Boulangerie (the World Cup of Baking, held in Paris every four years). Bread was one of three areas of competition (Viennoiserie and Artistic Design were the other two). It was in preparation for the competition, and then at the competition itself, that I initially began learning how to evaluate bread with a certain degree of objectivity. Each of the 12 countries that competed in Paris was required to make five different breads, and each bread was judged based on several criteria: weight, volume, taste, and aspect. Weight was a completely objective matter. For example, the baguettes were to weigh 250 grams. If they were within 5 grams of that, they received full score, with 1 point being lost the further the weight strayed from 250. Volume was gauged in relation to weight. In other words, if the baguette weighed 250 grams, was it a voluminous pillow of dough? Was it a truncated, dense stick of a loaf? Or was the volume appropriate to the weight? This too was a relatively objective aspect of the judging.

Taste was the third criteria considered by the judges, and here some of the lines did blur. After all, what one person deems fine is poor by another's standard. Nevertheless, one would expect that there would be reasonable commonality among the judges. The final category considered by the judges was that of "aspect." Aspect, a slightly vague and subjective consideration, included a multitude of assessments. For instance, were the cuts evenly spaced on the baguettes? Were they of equal length and depth? Did they cover the entire surface of the loaf symmetrically? How was the shaping? Was there a nice balance along the entire loaf? The inside of the loaf held other clues to quality. Was there a random, open cell structure? Was the interior of the baguettes tight and devoid of holes? Were there holes big enough to hide a mouse? How about the color of the crumb, was it snowy white or creamy? And were thin, translucent cell walls evident in the interior?

Characteristics such as creamy color, random cell structure, and translucency of the cell walls in the crumb of a white flour loaf are all suggestions of quality. They are not, however, guarantees of quality. Many a loaf looks great, but doesn't meet the ultimate standard of aroma and flavor, and these are the final arbiters. When we assess breads from this perspective, we look for a wheaty aroma. It may be subtle because, after all, the ingredients are few, and these few do not shout. Further, we want to smell the inimitable aroma of fermented flour. So, when you taste bread, do so without butter, or cheese, mayonnaise, meat, or anything at all. First, eat the bread, taking a bite that includes both crust and crumb. Chew slowly and conscientiously. The tongue picks up salt, sour, sweet, and bitter, so at first just a few sensations will be prominent. Keep chewing. As you inhale and exhale, your nose will register a myriad of subtle flavor notes. And at last, swallow. Did you enjoy a delicate nuttiness in the flavor? A suffusing sense of flour and fermentation? And finally, is there a long and lingering finish? Did you still taste the bread several minutes after swallowing? If we train ourselves to taste with care and give consideration to what we are experiencing, our vocabulary of bread assessment will grow, and along with it our discernment.

It is interesting to see words like *subtlety, delicacy,* and *long finish* being used in relation to the taste of bread. But really it is not so unusual. Bread, after all, holds its place with wine and cheese as one of the three great fermented foods of Western culture, and these terms apply as much to bread as they do to the finest wines.