15 Baked Products: Batters and Dough

Introduction

This baked products chapter builds on knowledge of the functional properties of carbohydrates, fats, and proteins discussed in previous chapters. Specific batter and dough ingredients that are discussed in this chapter include previously studied commodities, such as flour, eggs, milk, fats and oils, and sweeteners. Among other important points, this chapter will view the functions of various ingredients in a *general* manner and the role of those ingredients in *specific* baked products.

A majority of baked products contain flour (of course not flourless cake!), especially wheat flour, as the primary ingredient. Baked products vary significantly in their fat and sugar content. Pastries and some cakes are *high* in fat, whereas other cakes such as angel food cake and breads may be *low-fat* or *fat-free*. Many baked products such as breads, cakes, and cookies are increasingly available as gluten-free, accommodating a growing segment of the population.

Batters and *dough* each contain different proportions of liquid and flour and therefore are manipulated differently—by stirring, kneading, and so forth. Some batters and dough contain a well-developed gluten protein network, while others do not have this characteristic and, as mentioned above, are gluten-free. In some food products, the network may hold many additional substances, such as starch, sugar, a leavening agent to produce CO_2, liquid, flavoring agents, and perhaps eggs and fats or oils. Other items including salts or acids are also found in baked products.

The gas cell size and shape as well its surrounding ingredients create the "grain" and texture of a baked product. Most batters and dough are "foams" of coagulated proteins around air cells. For example, angel food cakes and sponge cakes form definite foam structures.

By way of introduction, a *quick bread* is one that is relatively quick to mix before baking and is leavened primarily by added *chemica*l agents, such as baking powder or baking soda, not by yeast. It may be leavened by steam or air. Pancakes and waffles, biscuits, and muffins are examples. *Yeast breads*, on the other hand, are leavened *biologically* by yeast and are therefore not quick, rather more time-consuming to prepare. More detailed discussion on leavening will follow.

Ready-to-eat (r.t.e.) and ready-for-baking products continue to replace some baking "from scratch." Low-fat products are popular. Proper storage extends shelf life.

Imagination is the limit to creative baked products!

Classes of Batters and Dough

Batters and dough are classified according to their ratio of liquid to flour (Table 15.1), and

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Table 15.1 Batters and doughs: ratio of liquid to flour

Type	Liquid	Flour
Batter		
Pour batter	1 Part	1 Part
Drop batter	1 Part	2 Parts
Dough		
Soft dough	1 Part	3 Parts
Stiff dough	1 Part	6–8 Parts

they each utilize various mixing methods. While exact ingredient proportions of both batters and dough vary by recipe, for use as a planning guide or in recipe analysis, the ratios in Table 15.1 provide useful guidelines.

Batters are flour–liquid mixtures that are *beaten or stirred*, and as their formulations indicate, these incorporate a considerable amount of *liquid* as the *continuous medium*. Batters are classified as either (1) pour batters or (2) drop batters. *Pour* batters, such as those batters used in the preparation of items such as pancakes and popovers, are thin and have a 1:1 ratio of liquid to flour. *Drop* batters contain *more* flour than a pour batter with a ratio of 1:2 of liquid to flour. Muffins and some cookies are examples of products prepared with drop batter.

Dough is distinguished from batter by being thicker than batter. Dough does not contain a lot of liquid and is *kneaded*, not beaten or stirred. The *flour/gluten matrix*, not liquid (as batters), is the *continuous medium*. The flour mixtures are classified as soft or stiff dough. For example, *soft* dough, such as that used in biscuit preparation, or yeast bread has a liquid-to-flour ratio of 1:3. *Stiff* dough may have a ratio of 1:6 or higher and might be used for cookies or pastry dough, such as piecrust.

Gluten

Gluten, or the gluten matrix, is noted for its *strong*, three-dimensional, viscoelastic structure that is created by specific proteins. Specifically, it is the hydrophobic, *insoluble gliadin proteins* that contribute *sticky*, fluid properties to the dough and the *insoluble glutenins* that contribute ***elastic*** properties to the dough. Not all flour and therefore not all dough form gluten. Non-gluten flours contain *starch* that provides some structure; however, it is *gluten* protein that provides the major *framework* for many batters and dough.

Upon hydration and manipulation, the two proteins aggregate and form disulfide bridges, producing a gluten protein matrix that is subsequently *coagulated* upon baking. This is a three-dimensional structure capable of stretching without breaking, although it may break with overextension if dough is kneaded too much. The gluten determines the texture and volume of the finished product. Oftentimes directions will state, "rest the dough," and to the extent that the dough contains gluten, resting serves to relax the gluten structure (Fig. 15.1).

Many baked products contain flour that is derived from wheat and especially *hard wheat*, *rye*, *or barley* (see Chap. 6). These flours have ***gluten-forming potential***, while oat (more below), corn, rice, and soy do *not* have gluten-forming potential due to inherent differences in protein composition. Oats may be cross-contaminated with gluten during shipping or processing and are therefore often avoided by persons following a gluten-free diet. (According to many researchers, including those at the University of Chicago Celiac Disease Center, "Regular, commercially available oats are frequently contaminated with wheat or barley. However.... pure, uncontaminated oats can be consumed safely in [limited] quantities....It is important that you talk to your physician and your registered dietitian prior to starting oats.")

Yeast breads made with wheat flour are kneaded to create an extensible structure. The dough requires extensive ***gluten development*** to be able to expand. *Without* gluten, the *latter* types of flour listed above are incapable of any structure expansion when CO_2 is generated from yeast.

The gluten structure in a batter/dough mixture is embedded with numerous recipe ingredients. This includes the starch in the flour which itself contributes to dough rigidity, added fat or sugar,

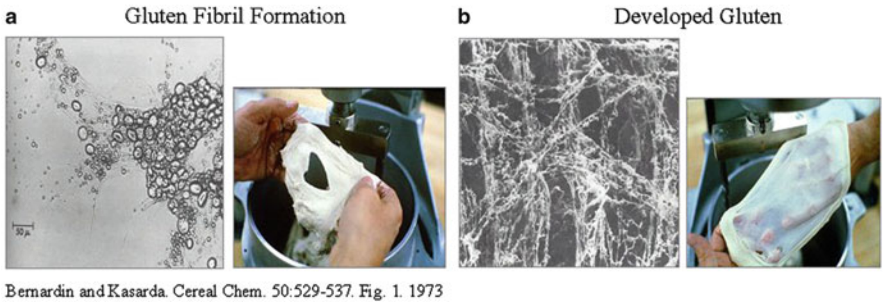

Fig. 15.1 Gluten Fibril Formation. Bernardin and Kasarda. Cereal Chemistry. 50:529–537. Figures 15.1 and 15.2 (1973)

liquid, or leavening. These added ingredients (see Functions of Various Ingredients in Batters and Dough) influence the development of the gluten structure, the dough strength, and the finished baked product. For example, dough does not reach its maximum strength when the recipe includes high levels of (1) sugar, which competes with gliadins and glutenins for available water, or (2) fat, which *covers* flour particles and prevents water absorption needed for gluten development.

Dough such as biscuit dough has a liquid-to-flour ratio that makes it more likely than *batters* to become tough due to the large proportion of flour. This is true especially if the biscuits are overstirred or overkneaded resulting in extensive development of gluten.

Of the *batter* types, *pour* batters do not exhibit a significant difference in gluten development between *adequately mixed* and *overmixed* batter. *Drop* batter, such as a muffin batter, has more flour than a pour batter and consequently has a greater chance of developing gluten. If gluten is *overdeveloped*, batters and dough may exhibit obvious internal holes in a tunnel formation (see Mixing Methods for Various Batters and Dough).

With the use of *less* flour, *less* gluten is likely to be produced. It follows that *sifted* flour also incorporates *less* flour into a recipe, and so there is *less* gluten-forming potential compared to an equal measure of *unsifted* flour. The sifting process also incorporates air that provides leavening.

CULINARY ALERT! Specifying "flour, sifted" or "sifted flour" as directions in a product formulation/recipe are two different instructions. Measure first, then sift is the former; sift first, then measure is the latter!

With the aim of physically seeing the gluten in flour, manipulated dough may be washed in *cold water* (not hot water as heat will gelatinize starch). This washing removes the nonprotein components of the flour. Then, only the gummy gluten (remember—a protein) component of flour remains. It resembles already chewed chewing gum! When this gluten ball is subsequently baked, the entrapped water becomes steam and leavens the now hollow structure. Figure 15.2 shows the size of raw and baked gluten balls, which indicates the relative amount of gluten in the various types of flour. Of course, some flours contain *no* gluten-forming proteins. In that case, there is no gummy material created or retained and therefore no dough to show in a picture.

Gluten in a dried form may be added to other flours, providing extra strength and several times the gluten-forming potential of that flour. Extracted gluten is used to fortify protein content of some breakfast cereal, for binding breading on meat, poultry or fish, and as an extender for fish and meat products. As well, nonfood uses of gluten may be as a constituent of mascara and pharmaceutical tablets.

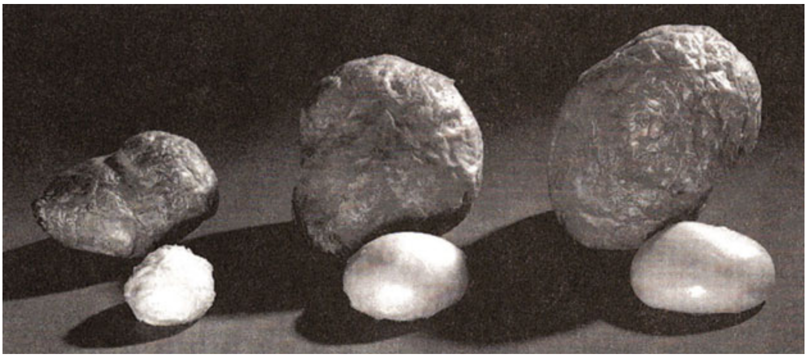

Fig. 15.2 Unbaked and baked gluten balls. *Left to right*: gluten balls prepared from cake flour, all-purpose flour, and bread flour (*Source*: Wheat Flour Institute)

A view of the Codex Standard for gluten-free food, daily gliadin consumption, and studies on the safety of wheat starch-based gluten-free foods is found in other literature (Thompson 2000, 2001).

Function of Various Ingredients in Batters and Dough

Certainly baked products do not necessarily need all of these ingredients that follow. The watery mixture of substances that these ingredients create bakes *around gas cells* and subsequently determines the texture, flavor, and appearance of baked products.

Flour Function

Flour provides structure to baked goods because of its *protein* and, to a lesser degree, its *starch* components. For example, to the extent that the *gluten-forming proteins* are present in flours, there is dough elasticity and structure (see Gluten) due to formation of a gluten matrix. *Starch* contributes structure to a batter or dough, as it gelatinizes and makes the *crumb more rigid*. Additionally, flour is a source of fermentable sugar that is acted upon by yeast in producing CO_2 for leavening.

Many types of flour (Chap. 6) are used in the preparation of baked goods.

Wheat flour is derived from the endosperm of *milled* wheat and is the most common flour used in the preparation of baked goods in the United States. Specifically, ***all-purpose flour*** is chosen for use. It is produced by blending *hard and soft* wheat during milling and has applications in many baked products. Consumers refer to it simply as "flour."

- *Hard* wheat flour, such as bread flour, has a *high* gluten potential that is important for structure and expansion of yeast dough. It absorbs *more water* than an equal amount of soft wheat flour.
- *Soft* wheat flour, such as cake flour, contains *less* gluten-forming proteins and is effectively used in the preparation of the more tender (due to less gluten) cakes and pastries. An equal amount of soft wheat flour absorbs *less water* than hard wheat flour, and it becomes important to know that the two flours are not an even exchange.

CULINARY ALERT! All "flour" used in a recipe is not created equal! High-protein "hard" flour absorbs more water than low-protein "soft" flour, and thus flour cannot be interchanged in all cases.

Whole wheat flour differs from *wheat* flour, as it contains *all* of the three kernel parts, including the endosperm, germ, and bran (Chap. 6). *Bran* has sharp edges that *cut* through the developing protein structure and results in a *lower*-volume baked product, especially when a recipe replaces *all* of the flour with *whole wheat* flour.

Improved food results are seen when the whole wheat flour is *finely ground*. Finely ground flour introduces *less* sharp edges that cut and can reduce volume. Due to the presence of whole wheat's *bran*, the percentage of protein is lower in whole wheat flour than refined wheat flour.

Whole wheat flour also contains the *germ* that may cause rancidity over time. Yet, baked products may not remain uneaten for too long though!

CULINARY ALERT! Generally, when a whole grain flour is desired in a baked product, the recipe may replace the flour with no more than *half* whole grain flour used in combination with *half* bread flour.

While wheat flours are the most common types of flour used in baked products, *non-wheat* flours such as corn, rice, and soy are also popular in bread making. When the formulation combines use of these flours with wheat flour, there are more desirable baking results.

Despite the type of flour used, it is typically *sifted* prior to measurement, as sifting standardizes the amount of flour added to a formulation and assures consistency in product preparation. Consistency is *also* more likely when ingredients are *weighed*, not *measured*.

Flour shows variance in the *same* brand of flour milled in *different milling locations* throughout the country. Due to these variations the same recipe may yield a slightly different finished product in different locations.

CULINARY ALERT! Adhere to appropriate measuring techniques, as well as local standardized recipes and flour type, especially when cooking/baking or in various parts of the country or world!

Liquids Function

Liquids are crucial in hydrating the *proteins* required for *gluten* formation and the *starch* element that undergoes gelatinization. These proteins and starch form the texture of the baked crumb. Additionally, liquids are the solvent for dissolving many recipe ingredients such as the leavening agent, baking powder, and baking soda, as well as salt and sugar. Liquids produce steam that leavens and expands air cells during baking.

According to federal regulations, the water level of a finished commercially prepared bread loaf may not exceed 38 %. *Liquids* though may contribute *more* than water. For example, while *milk* contains a very high percentage of water, it also *contains protein*, *milk salts*, and the *milk sugar lactose*. Juices, sugar syrups, eggs, and so forth may also be part of the liquid in a recipe.

In general, its lactose milk produces a softer crumb, holds moisture in the product, and contributes both flavor and color from the Maillard browning. The *near-neutral pH* of milk causes it to act as a buffer, preventing an acid environment that would be unacceptable to the growth of baker's yeast.

The practice of *scalding* milk is thought to be *unnecessary*. However, milk that is *not* scalded may contain whey protein that results in *diminished volume and poor quality*. This negative effect is especially true with the use of reconstituted, scalded nonfat milk solids (NFMS). *Unreconstituted* NFMS powder may also be added to recipes to increase *nutritive value*.

Leavening Agents Function

Leavening *agents* are presented in more detail in a later section of this chapter. Overall, leavening agents raise dough or "make light and porous." They include *air*, *carbon dioxide* (CO_2), and *steam* discussed below. Virtually, *all* baked products are leavened to some extent, if not solely, by *air*. The amount of air depends on the mixing method, sifting flour prior to addition, beating, creaming, and so forth. Consequently, there may be great variance in the *amount of air* that is incorporated into a batter or dough mixture.

Carbon dioxide gas is a leavening agent produced *chemically* by baking soda and baking powder. It is produced *biologically* by yeast. These agents fill existing air cells and the gluten structures that then expand with the CO_2 they produce.

A third leavening agent is steam. *Steam* works in combination to further expand cell size, making batters and dough light and porous. Leavening agents make foam out of batters as they fill air pockets or cells, contributing to the ***grain*** of the product. Holes in the crumb may be large or small; they may be intact or exploded.

Eggs Function

Eggs function in various manners in the batter or dough. They are *binders*, holding ingredients together. The *whole eggs* and *yolks* contain emulsifiers that distribute fat in the batter (a greater percentage of egg is necessary in a high-fat formulation compared to a low-fat or high-liquid formulation). Eggs leaven, provide coagulated structure, nutritive value, color, flavor, and more.

Egg whites contribute aeration and *leavening* when beaten due to the presence of air cells that are filled with CO_2 or expanded by steam. Egg whites produce a lighter, drier finished product. Eggs contribute elasticity to products such as popovers and cream puffs; thus when *omitted* from a formulation, the baked product is significantly (and unacceptably) lower in volume.

Structure provided by *flour* proteins forming a gluten matrix has been discussed previously. *Egg* proteins contribute to the structure as well, as they *coagulate* by heat, beating, or a change in pH. *Egg whites* incorporate air and may play an important part in *nutrition* as they function as a substitute for a portion of the whole egg in a formulation, thus reducing cholesterol levels.

The color and flavor imparted by eggs is especially significant in specialty ethnic and holiday breads and cookies. (More information on eggs is contained in Chap. 10.)

CULINARY ALERT! ***Large***-size eggs are generally used in a formulation that requires the addition of eggs.

Fat Function

Fats and oils are discussed in Chap. 12, and the reader is referred to that chapter for more specific information. Fat functions in *various* ways in batters and dough as is seen in Table 15.2 that illustrates effects of fats and oils on baked products. Fats and oils *tenderize* baked products by *coating* flour proteins in the batter or dough and physically interfering with the development of the gluten protein. They *shorten* by controlling gluten strand length; they create the *flakes* or *dough layers* seen in biscuits or piecrust. Fats *leaven* by incorporating air (creaming solid fats with sugar). Fats and oils help *prevent the staling* process of baked products.

Plastic fats such as hydrogenated shortening or some other solid fats may be spread or perhaps molded to shape; they do not pour. Hydrogenated vegetable shortenings and lard may contain emulsifiers (monoglycerides or diglycerides). These emulsifiers increase fat distribution and promote greater volume of the developed protein matrix, allowing it to stretch more easily without breaking.

Polyunsaturated oils yield a more ***tender***, mealy, and crumbly product than *saturated* fats. This is because the oil covers a larger surface area of flour particles than *saturated* fat, and it helps control/limit absorption of water (Chap. 12). Saturated fat such as lard covers less and produces a less tender, yet ***flaky***, piecrust with many layers in the dough. As discussed in Chap. 12, these two attributes cannot exist together.

Clearly when milk, especially whole milk, is used in a recipe, it contains *more* fat than juices or

Table 15.2 Effects of fats and oils on baked products

Coating and mechanical tenderizing effect—Fats and oils shield gluten protein from water, thus physically interfering with the hydration needed for gluten development. Both fats and oils tenderize baked products by coating, although oil (liquid at room temperature) coats more completely and yields a more tender product than solid fats; if coating is extreme, the texture of the product will be mealy, and the dough will show reduced gluten formation Fats containing emulsifiers help water and fat to mix and may promote the stretching of gluten strands, yielding a higher volume of the baked product
Shortening—Fats and oils minimize the length of developing gluten protein platelets; that is, they keep them short
Flakiness—Plastic fat that is cut into pea-sized chunks in piecrust doughs (or smaller in biscuits) contributes the characteristic of flakiness to baked products as it melts in the dough, forming layers in the dough. Fats contribute *flakiness*, and oil provides *tenderness*
Leavening—Plastic fats may be creamed in order to incorporate air and aerate batters and doughs
Less staling—Fats with monoglyceride addition, such as hydrogenated shortenings and commercially available lard, soften the crumb and function to retain moisture. It is primarily the amylopectin component of starch that forms a dry crumb

water, and therefore milk creates a *more* tender finished product than either juices or water. *Chilled* oils or fats exhibit slightly more *flakiness* in the baked product compared to room temperature versions, as the *covering potential* is reduced.

CULINARY ALERT! In order to reduce saturated fat intake and for culinary success, *well-chilled oils* may be utilized instead of room temperature oils.

Cup for cup, the various fats and oils *cannot* be substituted for one another and produce the same quality of baked product.

- Oils, hydrogenated vegetable oils, or animal fat (such as lard) are *100 %* fat.
- Margarine and butter contain approximately 20 % water.
- Reduced-fat "spreads" have an even *higher* percentage of water than margarine.

Fats containing water in the mix are *less* effective in their shortening ability than 100 % fats. Often, specially modified recipes are required to assure success in baking with reduced-fat replacements.

Baked products such as angel food cake do *not* contain added fat in the formulation, whereas other products such as shortened cake and pastries are high in fat content. With a low-fat modification, products may be missing some of the flavor, tenderness, or flakiness that fat provided in the original version.

CULINARY ALERT! As appropriate, 1 cup of margarine or butter may be substituted with 7/8 cup of oil.

Salt Function

Salt is a *necessary* component of yeast breads because it dehydrates yeast cells and controls the growth of yeast with its CO_2 production. In typical yeast dough the salt exerts an *osmotic effect*, competing with other substances for water absorption. Specifically there is *less* water for gluten development and *less* for starch gelatinization in salted yeast dough compared to unsalted dough. Salt contributes *flavor* to baked products.

The *absence* of salt in yeast bread dough allows rapid yeast development and rapid rising. This produces a collapsible, extremely porous structure, as gluten is overstretched and strands break.

CULINARY ALERT! Salt is a necessary component of yeast breads—its use controls overproduction of yeast.

Sugar Function

In addition to contributing flavor, sugar functions in many additional ways in batters and dough. The presence of sugar makes a product tender. This is because as the sugar in a recipe *competitively absorbs water* (instead of flour proteins and starch), there is *less* water available for gluten formation and less for starch gelatinization. Sugar also *elevates the temperature* at which the protein coagulates and starch gelatinizes, thus extending the time for CO_2 to expand the baking dough.

Sugar is a *substrate for the yeast* organism to act upon, producing CO_2, acids, alcohols, and a number of other compounds. Granulated white sugar, brown sugar, corn syrup, honey, and molasses are substrates for yeast, whereas artificial sweeteners cannot be fermented. Sugar exhibits *hygroscopic* (water-retaining) tendencies. Therefore baked products may become overly moist, gummy, or runny, especially if the formulation is high in fructose (i.e., honey). Reducing sugars, such as the lactose in milk, provide browning due to the Maillard browning reaction, and sugars also caramelize.

The amount of sugar usage varies. A *small* amount of sugar is helpful to include in yeast bread formulations because it is fermented by yeast to produce CO_2. *A large* amount (more than 10 % by weight) *dehydrates* yeast cells and *reduces* dough volume. Thus, a sweetened dough requires more kneading and rising time due to this osmotic effect of sugar. High levels of sugar are more easily tolerated in breads and cakes leavened by *baking soda or baking powder* than by *yeast*, since yeast cells are dehydrated by sugar. (As shown later, there may be occasions for using both leavens.)

Further types of sweeteners include the following:

Honey may be used in baked products. It imparts varied flavors. When honey is used as a baking ingredient, it makes a sweeter and moister baked product because it contains *fructose*, which is *sweeter* and *more hygroscopic* than sucrose.

CULINARY ALERT! One cup of sugar in a recipe may be replaced by 3/4 cup of honey plus 1 tablespoon of sugar; liquid is reduced by 2 tablespoonfuls.

Molasses imparts its own characteristic flavor that may be very strong. It may be used as the sweetener in baked products, yet, because it is more acidic than sugar, it should *not* be used to replace *more than half* of the total amount of sugar in a recipe. In order to control acidity, it may be necessary to add a small quantity of baking soda. As is the case with honey, when molasses is substituted for sugar, there needs to be a reduction in the amount of liquid in the recipe.

Sugar substitutes provide sweetness; however, they do not provide the functional properties of sugar, including browning, fermenting, tenderizing, and hygroscopic properties of sugars (see Chap. 14). Among sugar substitutes, an equal replacement of one sugar substitute for another, by weight, is *not* possible due to inherent differences in bulk and sweetness. *Acesulfame K*, *aspartame* (if encapsulated), and *saccharin* are examples of heat-stable sugar substitutes successfully incorporated to some degree into baked products (more in Chap. 14).

The Leavening Process of Baked Products

Leavening of quick breads and yeast breads occurs when the air spaces or gluten structure is filled with a leavening agent. For example, after gluten has formed in dough and the dough has subsequently been fermented, the gluten structure becomes extensible for the leaven inside. As previously discussed, ***leavening** agents* include air, steam, or CO_2, which become incorporated into the structure. The latter is produced either biologically or chemically.

As dough *is proofed* or rises in its final rising (usually yeast dough is raised two times), the gluten structure expands, and dough increases in volume and makes a product light and porous.

Air as a Leavening Agent

Air, which is incorporated to some extent into *almost every* batter and dough, expands upon heating and increases the volume of the product. It may be the only leavening agent in “unleavened” baked products such as some breads, crackers, or piecrusts. Air may be incorporated by *creaming* fat and sugar for a cake, by *beating* egg whites/whole eggs for angel food or sponge cake, by sifting ingredients, or by *folding* (lifting and turning) the airy egg into the mixture. After its introduction into the food, air cells expand with heat in baking, and another leaven, such as steam or CO_2, diffuses into the air space, enlarging it.

Steam as a Leaven

Steam too partially leavens *almost everything*. One part of water creates 1,600 parts of steam vapor. Steam is produced from liquid ingredients, including water, juices, milk, or eggs. Products such as cream puffs or popovers are dependent on steam formation for leavening and a hollow interior. They obtain their characteristic high volume and hollow interior as dough protein expands due to steam development and as the egg protein denatures and coagulates. A *high* liquid-to-flour ratio and a *high* oven temperature are needed for water vaporization and dough expansion in products leavened mainly by steam.

Carbon Dioxide as a Leaven

Carbon dioxide is a *major* leavening agent in batters and dough. The amount required in a formulation is proportional to the amount of flour. For example, a formulation that is high in flour (dough) requires more CO_2 production for leavening than does a high-liquid (batter) product; therefore, the recipe must contain *more* of the ingredient responsible for forming CO_2.

Chemical Production of CO_2

CO_2 may be produced *chemically* by the reaction of sodium bicarbonate with an acid (wet or dry), or it may be produced *biologically*, through bacteria or yeast fermenting sugar. CO_2 is easily *released* into a batter and it may also easily *escape*, becoming unavailable for leavening. This occurs if a batter or dough is left unbaked for an extended time period, or if the gluten structure is not sufficiently developed to allow extension with the CO_2.

Baking Soda

One means of chemical leavening is by *baking soda* or sodium bicarbonate. It chemically produces CO_2 as follows:

$NaCO_3$	+	heat → Na_2CO_3	+	CO_2	+	H_2O
Sodiumbicarbonate		Sodium carbonate		Carbon dioxide		Water

When incorporated *alone*, baking soda reacts *quickly* with heat and CO_2. It may *escape* from the raw batter before it is able to leaven. Therefore, baking soda must be *combined* with another substance to make it useful. The choices are either (1) *liquid acid* or (2) *dry acid*, plus liquid, in order to *delay* production of CO_2 and prevent escape from the mixture. Examples of liquid and dry acids are as follows:

- Liquid acids—applesauce, buttermilk, citrus juices, honey, molasses, and vinegar
- Dry acid—cream of tartar (potassium acid tartrate, a weak acid), shown below

$HKC_4H_4O_6$ +	$NaHCO_3$ →	$NaKC_4H_4O_6$
Cream of tartar	Sodium bicarbonate	Sodium Potassium tartrate
+ CO_2	+ H_2O	
Carbon dioxide	Water	

If a batter or dough is made *too alkaline* with the addition of baking soda, sodium carbonate is produced in the food product, and it forms a *soapy flavor*, *spotty brown color*, *and yellowing* of the flavonoid pigment. This may occur in buttermilk (soda–acid) biscuits, if soda is present in greater amounts than the acid with which it reacts. Soda–acid biscuits exhibit *more* tenderness than baking powder biscuits because the *soda* softens the gluten.

In contrast to alkalinity, the pH may be *too acidic*. If it is too acidic, baked products such as biscuits exhibit whitening in color.

CULINARY ALERT!

- Baking soda is added to the recipe ingredient mixture along with the *dry* ingredients. If it is added with the *liquid* ingredients, CO_2 may be prematurely released into the liquid and escape from the mixture during manipulation.
- Baking soda may be used to neutralize mildly acidic juice.

Baking Powder

A *second* means of supplying CO_2 gas *chemically* is via the use of baking *powder*. It was first produced in the United States in the early 1850s and quickly provided consumers with the convenience of a premixed leaven. Baking powder contains three substances: sodium bicarbonate (baking soda), a dry acid, and inert cornstarch filler. The starch filler keeps the soda and acid from reacting with each other prematurely and standardizes the weight in the baking powder canister.

Commercial baking powder must yield at least 12 % available CO_2 gas by weight (each 100 g of baking powder must yield 12 g of CO_2), and home-use powders yield 14 % CO_2.

Baking powders are classified in several manners. One method is according to the *type of acid* component. The acids differ in strength, and thus each determines the rate of CO_2 release. While in the past, tartrate and phosphate were used as the dry acid, now consumers use the more common *SAS* phosphate (sodium aluminum sulfate phosphate).

Baking powders are also classified according to their *action rate*, or how quickly they react with water and heat to form CO_2. A *fast-acting* baking powder, such as the monocalcium phosphate, is a *single-acting* powder whose soluble acids release CO_2 almost *immediately* upon moistening/mixing with liquid at room temperature. The SAS phosphate is *slow*-acting and a *double-acting* powder that releases CO_2 *two* times. The first release of CO_2 occurs as the mixture is *moistened*; the second occurs as the mixture is *heated*.

If an *excessive* quantity of baking powder is added to a formulation, cell walls may be stretched and break. This breakage results in a coarse-textured, low-volume product—due to an overstretched, collapsed structure and release of CO_2 bubbles. The use of excessive baking powder also results in a *soapy* flavor, *yellow* crumb, and overly *browned* exterior.

Cracks may form in some SAS phosphate baking powder used in biscuits due to attempted leavening with insufficient dough stretching. This might be due to inadequate manipulation of dough required for gluten development.

Inversely, if *too little* baking powder is used, the product is *not* sufficiently leavened. The finished baked product is soggy with a compact grain of small air cells in the batter or dough.

A distinction between the use of baking *soda* and baking *powder* is seen when *baking* various biscuits. For example:

- *Baking soda* + buttermilk (liquid acid) for buttermilk biscuits (baking soda requires an acid)
- *Baking powder* for baking powder biscuits

The occasional inclusion of *both* baking powder and baking soda may be necessary in a recipe if the amount of soda and liquid acid would not amply supply the CO_2 that is needed to leaven the mixture.

CULINARY ALERT! One teaspoon of baking powder is replaced by 1/4 teaspoon baking soda and ½ teaspoon of cream of tartar.

Biological Production of CO_2

Leavening may occur by the abovementioned nonfermentation methods, using air, steam, or chemical CO_2 production. Leavening may be the result of *fermentation*, the *biological* process in which the microorganisms, *bacteria or yeast*, function to metabolize fermentable organic substances.

Bacteria

An example is *Lactobacillus sanfrancisco*. This is the bacteria responsible (along with a non-baker's yeast *Saccharomyces exiguus*) for forming sourdough bread. The bacteria function to degrade maltose, yielding acetic and lactic acid and producing CO_2. It is common that *starters* or *sponges* of dough containing the bacteria, along with yeast, may be saved from one baking and used in a subsequent baking (see below).

CULINARY ALERT! Commonly shared among friends in their home kitchens, a "starter" culture or "sponge" may be used in bread making. The starter is retained from a previous baking, and therefore fresh yeast is not required each time bread is prepared.

Yeast

The most common strain of yeast used in bread making is *Saccharomyces cerevisiae*. It is a microscopic, one-celled fungi, a plant without stems or chlorophyll that grows by a process known as budding—a new cell grows and comes from an existing cell. It releases zymase, which metabolizes *fermentable sugars*—***fermentation***—in an anaerobic process, yielding ethanol and CO_2 (with more yeast cells, more CO_2 is produced). Most of the alcohol is then volatized in baking and the CO_2 provides leavening. The three main forms of yeast used in food include those listed in Table 15.3.

Table 15.3 Forms of yeast

Active dry yeast (ADY)	
	1 teaspoon ADY = 1 cake of compressed yeast (CY)
	Contains approximately 2–1/4 teaspoons per envelope
	Leavens 6–8 cups of flour
	Has a longer shelf life than CY
	Less moisture than CY
Cake or compressed yeast (CY)	
	Moist yeast with starch filler
	Short shelf life—must be refrigerated or yeast cells die
***Quick*-rising dry yeast**	
	Is rapidly rehydrated
	Raises a mixture rapidly
	Is formed by protoplast fusion of cells

Yeast is a fungus that leavens. In the leavening process it is developed by warm water and fed by the substrate sugar, fermenting it to yield carbon dioxide. In the presence of liquid and temperatures of 105–115 °F (41–46 °C), each yeast cell rehydrates and *buds*, producing new cells (see below). Reaching temperatures *greater than* 130 °F (54 °C) has a negative effect (thermal death) on yeast development, and *colder temperatures* are ineffective.

Due to the osmotic pressure that sugar exerts, more time is necessary to leaven *sweetened* yeast dough. It is possible that leavening may utilize baking soda or baking powder (chemical leavens) along *with* the yeast (biological leaven), especially if the recipe uses a high level of sugar that inhibits gluten development and the subsequent rise. Either may be added to the dough at the second rise, to provide extra leavening.

CULINARY ALERT! Directions for using the more recently developed "quick-rise yeast" may differ from what the experienced bread maker has learned about how to use yeast. Best advice: read the label!

There is a noticeable effect of spices on yeast activity. Spices such as cardamom, cinnamon ginger, and nutmeg greatly *increase* yeast activity, as does the more savory addition of thyme. The use of dry mustard has the opposite effect and *decreases* yeast activity (Spice Science and Technology).

CULINARY ALERT! Think of the festive and holiday breads you create and the wonderful effect of the added spice.

Ingredients in Specific Baked Products

Through an application of previously presented *general* concepts, the role of ingredients in some *specific* baked products will be examined.

Yeast Bread Ingredients

Yeast breads are prepared from *soft dough* (1:3–1:4 ratio of liquid to flour) using *hard wheat* flours to form a gluten structure that is strong and elastic. The structure may contain starch and sugar or other ingredients such as eggs and fat. The yeast is responsible for the production of CO_2 within the gluten structure, and in turn, the CO_2 is responsible for the reduction of pH from 6.0 to 5.0.

Four mandatory yeast bread ingredients in the United States are *flour*, *liquid*, *yeast*, *and salt*. Additionally, sugar and the commercial enzyme α-amylase may be added during the commercial preparation of bread loaves. (The enzyme α-amylase is naturally present in flour and may cause *unwanted* hydrolysis of the starch; however, it may be added in order to form *desirable* structure and texture in bread making and in creating food for yeast. Starch-hydrolyzing enzymes in flour such as *amylase* are important dough ingredients in commercial bread making because they produce such fermentable sugars upon which yeast acts [α-*amylase* breaks off one glucose unit, at a time, immediately yielding glucose, and β-*amylase* breaks off two glucose units—yielding maltose].)

Yeast will be addressed later in this chapter; however, the following are yeast bread ingredients.

Flour. Yeast breads are made with *hard flour*. Adequate gluten development and viscoelasticity are required for the entrapment of the CO_2 evolved from yeast fermentation. Some flours are *not* suitable for bread making, as they do *not* have gluten potential. Isolated gluten may also be added to flour to yield high-gluten flour. The *starch* component of flour also contributes to structure as it is gelatinized. In part it is converted to sugar, which provides food for yeast.

Liquid. Liquid is necessary to hydrate flour proteins, starch, and yeast cells. Milk or water, warmed to approximately 105–115 °F (41–46 °C) allows yeast cells to begin development (to bud). Higher or lower temperatures do not activate yeast or may destroy it.

Salt. Salt is a *required* ingredient in yeast formulas. It is added for flavor and to control gluten development so that the gluten stretches sufficiently yet not too much, causing breaking. If salt is omitted from a formulation, a collapsible structure would result from weak, overstretched gluten.

Sugar. The initial incorporation of a *small* amount of sugar with yeast promotes the yeast growth. Sugar also functions to brown the crust of yeast breads by the Maillard browning reaction, and it tenderizes dough if added in large amounts. *High* amounts of sugar *inhibit* yeast development. With *high* amounts of sugar, *less salt* or *more yeast* may be added.

Optional Ingredients Used in Yeast Breads. Optional ingredients in yeast bread making are *many*, determined in part by cultural or family preference. Yeast breads may include *sugar*, *fat*, and *eggs*. Fat may be added for flavor and tenderness; eggs may be added to provide emulsification, for nutritive value, flavor, or color. The incorporation of various *spices* including ginger, cinnamon, cardamom, and thyme increases gas production in dough by chemically enhancing yeast fermentation.

CULINARY ALERT! Many ingredients from A to Z are added to batters and dough. This assortment includes apples, carrots, cheese, dried beans, citrus fruit zest, dill, herbs, nuts, olives, sun-dried tomatoes, and zucchini, to name a few!

Quick Bread Ingredients

Quick breads, as their name implies, are relatively *quick* to mix before baking and are baked immediately without the lengthy waiting period as required of yeast breads. The leaven is typically *chemically* produced by baking powder, baking soda, or steam and/or air and is *not biologically* created such as yeast. Quick breads include biscuits, loaf breads, muffins, pancakes, popovers, and waffles among the variety of other baked products.

Flour. *All-purpose flour* is used to provide an adequate gluten structure for quick breads. The high liquid-to-flour proportion in a quick bread formulation limits gluten development and yields a tender product. Too much flour may produce excessive gluten, tunnels, and a dry crumb.

Liquid. Water, juice, or milk may be used as the dispersing medium for sugar, salt, and the leavening agent. As the liquid is heated, it forms steam, which leavens, gelatinizes starch, and contributes rigidity to the crumb.

Eggs. Eggs provide *structure* as they coagulate. They emulsify quick bread batters, allowing the *lipid* part to combine with *liquid* due to the presence of phospholipids in the yolk. Eggs also impart nutritive value and color.

Fat. Various fats and oils are used in quick bread production. *High* levels of fat limit the development of gluten. *Oil* coats flour granules, *covering* them to prevent water absorption. For example, oil is used in pancakes and muffins, and *pea-sized* chunks of *solid fat* are used in the preparation of biscuits to form flakes.

When formulations are modified for health purposes, such as may occur with the substitution of *oil for fat*, there is a noticeable change of quality. For example, the absence of flakes in biscuits becomes apparent. When a formulation is reduced fat or fat-free, it produces a *less* tender crumb due to the *increased* development of gluten.

Leaven. Typically, quick breads are chemically leavened quickly, baking powder (e.g., baking powder biscuits) or baking soda and a liquid acid (e.g., buttermilk biscuits) [a substitution: 2 tsp. baking powder + 1 cup milk = 1/2 tsp. soda + 1 cup buttermilk].

Sugar. Sugar provides sweetness and tenderization. It also assists in the Maillard browning reaction. *High* levels inhibit gluten development.

Pastry Ingredients

Depending upon the specific product desired, the quantity and type of fat/oil, flour, liquid, and so forth will vary. Piecrust is made from a *high-fat* stiff dough that has one of two distinct features—either *tenderness* or *flakiness*. Pastries may also be made from layered puff pastry dough or from a thick paste such as *choux paste*—for cream puffs and éclairs. These latter two forms of pastry dough may rise to several times the raw dough size when baked.

The function of various ingredients in pastry is identified in the following chapter subsections.

Flour. Pastry flour is best to use because it is *soft wheat flour* that is low in protein. If unavailable, it may be created using a blend *of hard and instantized flour*. Pastry flour or the blend of flour produces *less* gluten than either all-purpose or hard wheat flour and yields a *more tender* product.

CULINARY ALERT! If all-purpose or hard flour is used when the recipe specifies pastry flour, recall that hard flour absorbs more water and therefore less of it must be used than soft types to yield a similar consistency.

Liquid. The liquid in pastry dough is chiefly water. Water hydrates flour, promotes gelatinization, and forms cohesiveness. A pastry may depend upon steam from an egg to leaven. As the liquid of egg changes to steam, it leavens the mixture, i.e., cream puffs, and it contributes a gel-like interior to the hollow wall. (Although not made from a thick paste or high-fat pastry, another hollow baked product is the popover, a quick bread made from a high-liquid pour batter.)

Fat. Solid pea-sized chunks of *fat* in pastries melt to form many *flaky* layers in a crust, such as a piecrust. The use of *oil* in a recipe coats flour particles and permits *less* hydration of the flour. With the use of oil, piecrusts will exhibit a crumbly mealy nature and produce a pastry crust that is *not flaky*, but *tender*.

Lard and *hydrogenated shortenings* are solid shortenings that produce *very flaky* pastries, while *butter* and *margarine* are solid at room temperature and contain 80 % fat and 20 % liquid, thus *reducing* flakiness. Reduced-fat and fat-free margarines do not contain sufficient levels of fat to function well in pastry.

Pastries that are typically *high in fat* will not be as tender if the recipe is subject to fat reduction (Chap. 12).

Other Pie Pastry Ingredients. A piecrust may contain other ingredients depending upon the pie type. For example, *savory* crusts for a quiche may contain cheese or herbs. *Sweet* dessert crust may contain other spices, chocolate, or sugar for color or flavor. If made with sugar, crusts easily brown.

Cake Ingredients

Cakes commonly contain *fat* and *sugar*. Obviously there are many types and varieties of cake! However, this discussion is applicable to typical layer cakes. Many of the ingredients affect the cake volume and texture. Some functions of cake ingredients are presented in the following subsections.

Flour. *Soft* wheat (7–8.5 % protein) cake flour is desirable for cakes. The soft flour particles are small in size, and the cake is more lofty and tender with a *finer grain* than hard flour with its higher gluten-forming ability. Thinner walls, increased volume, and a less coarse cake result from using soft cake flour.

If the flour is *bleached*, as is often the case with cake flour, there are two advantages: (1) the pigment is whiter and (2) the baking performance is improved because, among other characteristics, bleaching oxidizes the surfaces of the flour grains and weakens the protein limiting gluten development. Higher loaf volume and finer grain result.

CULINARY ALERT! At the household level, 1 cup of all-purpose flour minus 2 tablespoons is used to replace 1 cup of cake flour in a formulation.

Liquid. Liquid gelatinizes starch and develops *minimal* gluten. *Fluid* milk hydrates protein and starch, providing structure and crumb texture. The milk sugar, lactose, and protein are valuable in determining the color of a finished cake. Milk proteins combine with sugars in nonenzymatic, Maillard browning.

Eggs. The protein of whole eggs or egg whites provides *structure* and may toughen the mixture as the protein coagulates. Egg *whites* leaven because they are beaten to incorporate air and they provide liquid, which leavens as it becomes steam. *Sponge cakes* incorporate whole egg, and *angel food cakes* are prepared with beaten egg whites to create volume. Egg *yolks*, due to their lipoprotein content, function as emulsifiers. The addition of extra fat and sugar offsets the toughness of egg in a formulation.

Fat. Fat functions in tenderizing cakes, since it shortens protein–starch strands. It provides increased volume, especially if creamed in a recipe or if monoglycerides and diglycerides are used as emulsifiers in the fat. *Butter* in a formulation may require more creaming than hydrogenated shortening because it is not as aerated and it has a narrow plastic range (Chap. 12). *Lard* has a large crystal size and therefore creams less well than most plastic fats. *Oils* produce tenderization.

Fat in a recipe also functions to retain moisture in the mixture and it softens the crumb. Shortened cakes differ from sponge cakes in that the latter have no fat besides egg.

CULINARY ALERT! Extra fat in the form of sour cream or eggs provides tenderness and flavor.

Sugar. Sugar imparts a sweet flavor to cakes and is often added to cake batters in large amounts. It competes with the protein and starch for water and inhibits both *gluten development and starch gelatinization*. Sugar also functions to incorporate air when plastic fats are creamed with sugar prior to inclusion in a batter. Even if not creamed, its addition increases the number of air cells in the batter, contributing to the *tenderness* of the grain.

Leaven. Leavening is created in several ways. The grain shows evidence of numerous air cells that hold expanding gases released by the leaven.

The process of creaming fat and sugar incorporates air to leaven. Baking soda reacts with an acid ingredient to leaven. The use of chemical leavening by both baking soda and baking powder is common, as is steam and air.

Since early times (and applicable today), there were ingredients added to baked products to lengthen shelf life. Some of these ingredients included spices such as cinnamon, ginger, clove, and garlic as well as honey. Effective cleanliness including hand washing is also recommended for extending product shelf life.

Mixing Methods for Various Batters and Doughs

The *function* of batter and dough ingredients and *ingredients* in specific baked products has been addressed in former sections. This section covers *specific mixing methods* for various batters and dough.

The purpose of *mixing* is to distribute ingredients, including leavening agents, and to equalize the temperature throughout a mixture. *Dough* such as that in biscuits and pastries are manipulated by *kneading*; cakes, muffins, and pour *batters* are *stirred.*

CULINARY ALERT! Depending on the mixing method utilized, two baked products with the exact same ingredients and proportions may yield two different end results! Due to various mixing methods, the volume, texture, and grain size may differ.

Biscuits

Biscuits are quick breads made of *soft* dough. The recommended mixing method is to cut a *solid fat*, pea size or smaller, into the sifted, dry mixture. Next, *all* of the liquid is added, a ball is formed, and the dough is kneaded. Kneading (see Yeast Dough, Kneading) 10–20 times develops gluten and orients the direction of gluten strands, necessary to create flakes. It mixes all ingredients, such as the *baking powder or soda* and *acid*, which leaven.

Underkneading produces a biscuit that fails to rise sufficiently.

Overkneading or rerolling overproduces gluten and results in a smaller volume, *tougher* biscuit, which will not rise evenly because CO_2 escapes through a weak location in the gluten structure.

Cakes

Cake batters may be prepared by several different methods. *Conventionally*, they are mixed by first creaming a plastic fat with sugar, which provides aeration of the cake batter. Next, the egg is added, and the dry and wet ingredients are added alternately. A second method or *dump* method mixes all of the items and then adds the leaven at the end.

CULINARY ALERT! With a lack of creaming, product loftiness is sacrificed because the number of air cells that can be filled with CO_2 is reduced.

Muffins

Muffins are a quick bread prepared from *drop* batter. The optimal mixing method for muffins is to pour *all* of the liquid ingredients into *all* of the sifted, dry ingredients and *mix minimally*. Overmixing a high-gluten-potential batter develops long strands of gluten and results in the formation of tunnels or peaks in the muffin (see below).

Tunnels, or hollow internal pathways, form long strands of gluten, allowing gases to escape from the interior. Muffins may also take on a peaked appearance if the oven temperature is too high, allowing a top crust to form while the interior is still fluid and maximum expansion of the muffin has not occurred. A center tunnel forms for gases' escape, creating a ***peak***.

Of particular interest are:

Bran muffins: Pieces of the bran physically *cut through* the developing gluten strands during mixing, and thus, bran muffins do not rise as much as non-bran-containing muffins.

Corn muffins: Since corn, a non-gluten flour, is used in a formulation, it is best to mix it with an *equal* amount of wheat flour in order to obtain a desirable structure.

Pastries

The mixing method for pastry is similar to biscuit preparation. It involves cutting the large amount of solid fat into the sifted, dry ingredients, then adding all of the liquid.

The mixture may be is stirred, then kneaded, and cut to desired shape. Croissant pastry dough must be repeatedly *folded*, not stirred or kneaded, numerous times over the course of several hours. This folding produces layers in the dough.

If oil is incorporated, *well-chilled* oil restricts the covering potential of room temperature oil and produces a slightly flaky product.

Pour Batters

Food items such as pancakes, popovers, and waffles contain a high proportion of liquid to flour and do *not* require a definite manner of mixing. Overmixing a pour batter is *unlikely* to affect the shape or texture of the finished product due to the high level of water and low level of gluten development.

Dough, Yeast Dough

Preparation of yeast dough includes kneading, fermenting, punching down, resting, shaping, and proofing the dough.

Subsequent to combining all of the ingredients into a ball, *kneading* must occur to stretch and develop the elastic-like gluten. This is done by pressing dough down, folding it in half, and giving a half-turn to the dough in between each pressing and folding. ***Kneading*** incorporates and subdivides air cells, promotes evenness of temperatures throughout the dough (75–80 °F [27 °C]), removes the excess CO_2 (which may overstretch the gluten structure), and distributes the leavening agent.

Kneading may be accomplished by utilizing a heavy-duty mixer, bread machine, or food processor, perhaps requiring 10, 5, and 1–2 min, respectively. *Underkneading*, or use of non-gluten-forming flour, will produce less/no gluten strands and thus breads with less volume. *Overkneading* is also possible, especially with the use of machine kneading. If this is the case, the gluten strands may break, resulting in a less elastic mass of dough that fails to rise satisfactorily.

Subsequent to kneading, yeast dough is left to rise as yeast cells undergo *fermentation* where fermentable sugar is converted into ethanol and CO_2. The dough has doubled in size when the rise is complete. Then, the dough is *punched down*. Punching down is beneficial in that it allows the heat of fermentation and CO_2 to escape, introduces more oxygen, controls the size of air cells, and prevents overstretching and collapse of gluten. If the dough is allowed to rise *too much*, gluten is overstretched, causing the dough to be inelastic and inextensible.

This step of punching down the dough provides yeast contact with a fresh supply of food (the sugar) and oxygen. The dough is punched down and left to rest for 15–20 so that gluten strands *rest or relax*, and the starch absorbs water in the dough to make it less sticky. In this time period, fermentation continues and the gluten network becomes easier to manipulate.

Next is the rest period where gluten is relaxed. The dough is *shaped* and allowed to rise a second time—it is ***proofed***. In this second rise, the dough will *double* in volume as many more yeast cells have budded and produced additional CO_2. It is ready to bake when a slight indentation mark remains in the dough when it is pressed lightly with the fingers.

In the case of over-risen dough, it should be punched down again and allowed to rise a third time so that it is not baked in a condition where the overstretched structure will collapse. If the stretched gluten structure collapses, volume decreases due to CO_2 loss, and the texture is thus noticeably coarse, open, and dense instead of fine and even.

CULINARY ALERT! Knead enough however not too much!

Baking Batters and Doughs

Unbaked batters and dough are foams of watery substance surrounding air cells. This surrounding mixture forms the *grain* of the finished product as it "sets" or coagulates around air cells. Major product changes that occur during baking involve protein, starch, gases, browning, and importantly a release of aroma!

- *Proteins* in the flour, or added protein ingredients, harden or coagulate by heat.
- *Starch* granules lose their birefringence, swell, and gelatinize as they imbibe moisture.
- *Gases* expand and produce leavening.
- *Water* evaporates and a browning of the crust becomes evident due to the Maillard browning reaction.
- The *alcohol* by-product of yeast fermentation evaporates, albeit not completely.

The qualities of a finished baked product may be determined by the degree of manipulation (stirring, kneading) and oven temperature. The type of flour, the amount of liquid, and an almost unlimited list of possible added ingredients affect quality.

CULINARY ALERT! A curved and split top seen in a rectangular shaped baked cake is due to the setting of structure on the outer surface while the interior is still fluid.

In the oven for a few minutes, yeast breads will exhibit an initial rising of the loaf known as ***oven spring***. Then, the rise is due to expansion with heat, yeast's CO_2, and the steam from water.

Gases expand the gluten strands until they form a rigid structure. However, *over*-fermentation and *over*-proofing result in the ballooning of the loaf of bread, followed by a likely collapse in structure, as previously discussed. Flavor develops as the crust browns with water loss and aroma is released.

Altitude-Adjusted Baking

As a rule, cooking and baking differ at elevations other than at sea level—both above and below sea level. Around 1/3 of Americans live at high altitudes (which is anything over 3,000 ft).

Water boils at 212° at sea level and at a *lower* temperature at higher elevations—a few °C or approximately 10 °F less. For example, every 1,000-ft change in elevation up or down changes the boiling point by approximately 2°. Therefore water boils at a temperature of 202 ° F (94 °C) at 5,000 ft and at less than 200 °F at 7,500 ft. This equates to the fact that at higher elevations, foods cooked in water have to be cooked substantially longer to get them done. Even when water comes to a rapid boil, it is not as hot at high altitudes as rapidly boiling at sea level! It follows that baking requires an increase in time too.

When a product is baked at *high* altitude, there is less atmospheric resistance and it takes longer to bake. The lowered air pressure also tends to cause the air bubbles in baked goods to rise faster, producing increased dough expansion. Then these air bubbles escape to the atmosphere causing the cake to fall. The inverse is true regarding low altitudes and high atmospheric pressure where water boils at a higher temperature. Therefore, *local* instructions specific to the altitude must be followed in manufacturing, foodservice, or home recipes.

At high elevations (5,000 ft or more above sea level), a *reduction in sugar* and *less leaven* is needed. A reduction in sugar provides *less* competition for the water, and therefore water is available to develop a strong gluten structure. *Less* leaven prevents the overexpansion of dough that may so easily occur with the lower atmospheric pressure.

"With less air pressure weighing them down, leavening agents tend to work too quickly at higher altitudes, so by the time the food is cooked, most of the gasses have escaped, producing a flat tire. For cakes leavened by egg whites, beat only to a soft-peak consistency to keep them from deflating as they bake. Also, decrease the amount of baking powder or soda in your recipes by 15 % to 25 % (one-eighth to one quarter teaspoon per teaspoon specified in the recipe) at 5,000 ft, and by 25 % or more at 7,000. For both cakes and cookies, raise the oven temperature by 20° or so to set the batter before the cells formed by the leavening gas expand too much, causing the cake or cookies to fall, and slightly shorten the cooking time.

> "Flour tends to be drier at high elevation, so increase the amount of liquid in the recipe by 2 to 3 tablespoons for each cup called for at 5,000 feet, and by 3 to 4 tablespoons at 7,000 ft. Often you will want to decrease the amount of sugar in a recipe by 1 to 3 tablespoons for each cup of sugar called for in the recipe" (Food News Service, Brunswick, ME)."

"There are some standard adjustments you can make. At 7,000 ft., for each cup of liquid called for in the recipe, increase it by 3 to 4 tablespoons. For each teaspoon of baking powder called for, decrease the amount by 1/4 teaspoon. For each cup of sugar in the recipe, decrease the amount by 1 to 3 tablespoons."

"For cakes leavened by egg whites, beat only to a soft peak consistency to keep them from expanding too much as they bake. For both cakes and cookies, lower the oven temperature by 20 degrees or so and slightly shorten the cooking time. You will want to keep the changes on the small side the first time you prepare a recipe, and adjust as needed subsequently" (Food News Service, Brunswick, ME).

Death Valley in California is the lowest land point in the United States, 282 ft below sea level. Inversely compared to high altitudes, cooking and baking below sea level will require a decreased cooking time of 5–10 %. Baked goods will rise more slowly and retain more moisture at lower altitudes. Increasing the amount of baking powder or baking soda typically used at higher elevations may be necessary.

Storage of Baked Products

Proper storage of baked products extends shelf life and maintains the best flavor and texture. Covering and elimination of external air is a step normally taken to protect baked products; thus, a good wrap or airtight storage is recommended. Such storage may also deter staleness. For long-term storage, use of a freezer wrap prior to freezer storage minimizes dryness or freezer burn.

Nutritive Value of Baked Products

The nutritive value of baked products varies according to the type and amount of ingredients used in the formulation. The primary ingredient of many baked products is flour. However, there may be a significant amount of fat or sugar. Generally, food choices that provide less sugar and fat in the diet should be selected, as fats and sweets should be used sparingly.

Whole grains, fruits, grated vegetables such as carrots or zucchini, nuts, and NFMS may be used in recipes, providing appearance, texture, and flavor benefits and boosting nutritive value. Individuals following a gluten-free dietary regimen may avoid specific flours such as wheat and instead choose flour such as rice flour to bake.

Reduced-Fat and No-Fat Baked Products

Some baked products may be successfully prepared with a reduction in the fat content, and this modification may fit into many fat- or calorie-restricted diets. However, the product will be *less* tender and flavorful than the unmodified original counterpart. The result of reducing or eliminating fat is altered flavor, more gluten development, and less tenderness than a product with the standard amount of fat.

CULINARY ALERT! Reduced and low-fat baked products may not result in quality that is acceptable to all individuals.

Safety Issues in Batters and Doughs

Microbial Hazards

"Rope" is a condition attributed to bacilli *bacteria* in flour. It may be present in the field from which a crop was obtained to produce flour. Its presence causes a syrupy ropelike interior of bread—it stretches and appears as a rope! An acid environment (pH 5 or 4.5) prevents this growth of bacteria.

Mold spoilage is also possible. Therefore, mold inhibitors such as *sodium or calcium propionate* or *sodium diacetate* are commonly added to commercially prepared bread to inhibit mold and bacteria.

Nonmicrobial Hazards

Nonmicrobial deterioration may occur due to rancidity or staling (Chap. 5). Both terms have previously been discussed in earlier chapters. A little about staling is justified herein. Staling is defined as all those changes occurring *after* batters and dough are baked. It is thought that deterioration primarily involves recrystallization of amylopectin, and it includes a change in flavor, a harder, less elastic crumb, and less water-absorbing ability. In order to partially restore flavor, brief reheating is recommended. If heat is prolonged or too high, a dry crumb is evident.

Foreign substances also pose hazards if found in foods. Controls must be established and enforced to protect against deterioration and hazards (Chap. 16).

Conclusion

Batters and dough are made with different types and proportions of liquids, flour, and other ingredients such as leavening agents, fat, eggs, sugar, and salt. Depending on the amount of flour, batter may be a pour-type or drop batter, and dough may be soft or stiff. A formulation that includes wheat flour forms a protein network known as gluten, and liquid gelatinizes starch as the batter or dough bakes. Both gluten and gelatinized starch contribute to the structure of baked products. A quick bread is quick to prepare, whereas yeast breads require more lengthy time periods for the yeast to raise bread prior to baking.

Sugar and salt contribute flavor and exert an osmotic effect on dough as they compete with other added substances for water absorption. A small amount of sugar serves as the substrate for yeast in fermentation, whereas a large amount of sugar interferes with CO_2 development by dehydrating yeast cells. Salt is needed for control of yeast growth.

Baked products may be leavened with air, steam, or CO_2 that enlarges air cells and raises dough. Carbon dioxide may be produced biologically by yeast or chemically by baking powder or baking soda. Leavening is also accomplished by air or steam.

Fat is considered optional in some batters and dough and mandatory in other baked products. Liquid oil coats flour particles more thoroughly than solid fat, limiting gluten development and contributing tenderness. Solid fat, cut into pea-sized chunks or less, melts, forming layers in piecrusts and biscuits, respectively. Eggs may be added to batter and dough formulation.

Egg whites may be beaten to incorporate air; whole eggs or yolks contribute nutritive value, color, flavor, and emulsification. The nutritive value of baked products is dependent on the individual recipe ingredients.

Imagination is the limit to creative baked products!

Notes

CULINARY ALERT!

Glossary

All-purpose flour The flour created by a blend of hard and soft wheat milling streams.

Batters Thin flour mixtures that are beaten or stirred, with a 1:1 or 1:2 ratio of liquid to flour, for pour batters and drop batters, respectively.

Dough Thick flour mixtures that are kneaded, with a 1:3 or 1:6–8 ratio of liquid to flour for soft and stiff dough, respectively.

Elastic Flexible, stretchable gluten structure of dough.

Fermentation A biological process where yeast or bacteria, as well as mold and enzymes, metabolize complex organic substances such as sucrose, glucose, fructose, or maltose into relatively simple substances; the anaerobic conversion of sugar to carbon dioxide and alcohol by yeast or bacteria.

Flaky Thin, flat layers of dough formed in some dough such as biscuits or piecrusts; a property of some pastries that is inverse to tenderness.

Gluten Three-dimensional viscoelastic structure of dough, formed as gliadin and glutenin in some flour are hydrated and manipulated.

Gluten-forming potential Presence of the proteins gliadin and glutenin that may potentially form the elastic gluten structure.

Gluten development The hydration and manipulation of flour that has gluten potential.

Grain The cell size, orientation, and overall structure formed by a pattern or structure of gelatinized starch and coagulated protein of flour particles appearing among air cells in batters and dough.

Kneading To mix dough into a uniform mass by folding, pressing, and stretching.

Leavening To raise, make light and porous by fermentation or nonfermentation methods.

Oven spring The initial rise of batters and doughs subject to oven heat.

Peak A center tunnel where gases escape from a muffin.

Plastic fat Solid fat able to be molded to shape, but does not pour.

Proofed The second rise of shaped yeast dough.

Tender Having a delicate, crumbly texture, a property of some pastries that is inverse to flakiness.

Tunnels Elongated air pathway formed along gluten strands in batters and doughs, especially seen in over manipulated muffins.

Wheat flour Flour derived from the endosperm of milled wheat.

Whole wheat flour Flour derived from the whole kernel of wheat—contains bran, endosperm, and germ of wheat.

References

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