Chapter 2
Breadmaking Processes

In the same way that different bread varieties have evolved with the passage of time so have different methods which allow the conversion of flour and other ingredients into bread. In many cases the relationship between product and process is so strong that it may be wrong to consider them as separate issues. Just as there is no 'ideal' product so there is no 'ideal' breadmaking process. In reality each baker uses a breadmaking process which is unique, in that the combinations of ingredient qualities, formulations, processing conditions and equipment reflect the qualities of the products he or she is seeking to achieve. In practice many of the variations in such breadmaking processes are very small and usually consist of minor variations about a central 'standard' process, so that we are able to group many of the variations into a small number of more generic processes in order to consider the changes which occur within them and their contribution to final product quality.

Functions of the Breadmaking Process

All of the processes which have evolved for the manufacture of bread have a single, common aim, namely to convert wheat flour into an aerated and palatable food. In achieving this conversion there are a number of largely common steps which are used.

- The mixing of flour (mainly wheat) and water, together with yeast and salt, and other specified ingredients in appropriate ratios.
- The development of a gluten structure (hydrated proteins) in the dough through the application of energy during mixing, often referred to as 'kneading'.
- The incorporation of air bubbles within the dough during mixing.
- The continued 'development' of the gluten structure created as the result of kneading, in order to modify the rheological properties of the dough and to improve its ability to expand when gas pressures increase because of the generation

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of carbon dioxide gas in the fermenting dough. This stage of dough development may also be referred to as ‘ripening’ or ‘maturing’ of the dough.
- The creation or modification of particular flavour compounds in the dough.
- The subdivision of the dough mass into unit pieces.
- A preliminary modification of the shape of the divided dough pieces.
- A short delay in processing to modify further the physical and rheological properties of the dough pieces.
- The shaping of the dough pieces to achieve their required configurations.
- The fermentation and expansion of the shaped dough pieces during ‘proof’.[1]
- Further expansion of the dough pieces and fixation of the final bread structure during baking.

The main differences between individual or groups of breadmaking processes are usually associated with mixing and kneading, air incorporation, and the creation and development of the gluten structure, in summary all of those operations which in practice deal with the formation of a large dough bulk. The subdivision of the bulk dough and the processing stages for individual dough pieces do contribute to the modification of product quality but tend to build on the dough development created before subdivision of the bulk dough. The processing stages at the end of the sequence, proving and baking, are common to most breadmaking processes and differences between individual bakeries tend to be in the type of equipment used and small variations in conditions which are applied in the bakery equipment, e.g. time and temperature.

Dough development is a relatively undefined term which covers a number of complex changes in bread ingredients which are set in motion when the ingredients first become mixed. The changes are associated with first the formation of gluten, which requires both the hydration of the proteins in the flour and the application of energy through the process of kneading. The role of energy in the formation of gluten is not always fully appreciated and is often erroneously associated with particular breadmaking processes, especially those which employ higher speed mixers and short processing methods (e.g. the Chorleywood Bread Process).

[1] *The terminology used in baking can be confusing for many. This is especially true of two terms; fermentation and proof. Fermentation refers to the action of baker’s yeast in the dough on the sugars which are present with the subsequent evolution of carbon dioxide gas and small quantities of alcohol. Fermentation will occur in the dough whenever the conditions are ‘right’ for the yeast (mainly the availability of food and an appropriate temperature). There are two main times when fermentation occurs; after the dough has been mixed and before it has been divided into unit pieces and after the dough has been finally shaped and before it enters the oven. The former is most commonly referred to as ‘bulk fermentation’ or simply fermentation, while the latter is most commonly referred to as ‘proof’. This change in terminology logically allows the baker to understand which part of the process the dough has reached. In both cases ‘fermentation’ in the true sense occurs though the temperatures at which the stages are carried out are different with proof commonly being carried out at a higher temperature. A further complication is that bakers may refer to ‘first’ or ‘intermediate’ proof to define a short rest period which occurs after first moulding and before final moulding.*

Anyone doubting the validity of the need for energy in gluten formation should try a simple experiment which involves placing flour, water, yeast and salt together on a table and waiting for the gluten to form. They should then be encouraged to begin hand mixing of the ingredients to experience the transformation in the mixture which will occur. The best results in terms of improved bread volume and crumb softness will be achieved with vigorous and prolonged hand mixing and kneading. During the process of kneading, the dough, and more probably the ‘baker’, becomes warmer as energy is imparted to the dough. However, there is more to dough development than a simple kneading process.

In the process of developing a bread dough we bring about changes in the physical properties of the dough and in particular we improve its ability to retain the carbon dioxide gas which will later be generated by yeast fermentation. This improvement in gas retention ability is particularly important when the dough pieces reach the oven. In the early stages of baking before the dough has set yeast activity is at its greatest and large quantities of carbon dioxide gas are being generated and released from solution in the aqueous phase of the dough, along with steam and thermal expansion of the trapped gases. If the dough pieces are to continue to expand at this time, then the dough must be able to retain a large quantity of that gas being generated, and it can only do this if we have created a gluten structure with the correct physical properties.

Four physical properties of dough will concern us in breadmaking: resistance to deformation, extensibility, elasticity and stickiness. We can use the analogy of an elastic band to help understand the first three of these properties. When we stretch the elastic band in our hands a degree of force is required to change its shape as it resists deformation. If we apply only a modest force and release one end of the band then, because it is an elastic material, it returns to its original shape. If we once again stretch the elastic band and continue to apply force without releasing it we will eventually reach a point of extension when the elastic band snaps, which we could take as a measure of its extensibility. The fourth physical property, stickiness, is largely self-explanatory. After some materials have been compressed they will stick to the surfaces within which they are in contact, so that when the direction of the compressing force is reversed they exert an adhesion force before parting from the surfaces concerned.

Dough stickiness is the least desirable property for the baker because it makes dough processing difficult. This is especially true in plant bakeries where the tendency for the dough to smear onto the surfaces of processing equipment leads to an accumulation of dough material which eventually impedes the progress of dough pieces and may bring the plant to a halt. Yet dough is not in itself sticky but becomes so when it is subjected to stress and shear. The effect of the latter is especially important and occurs when blades are driven through dough (e.g. during dividing of the bulk dough into unit pieces) or when a surface of the dough is moved at a different rate to its bulk (e.g. during mixing and moulding). Typically the stickiness observed with dough immediately after it has been sheared will reduce with even a short resting time. Because the rheology of dough changes with a short rest or further manipulation and this has made the objective assessment of stickiness’ difficult

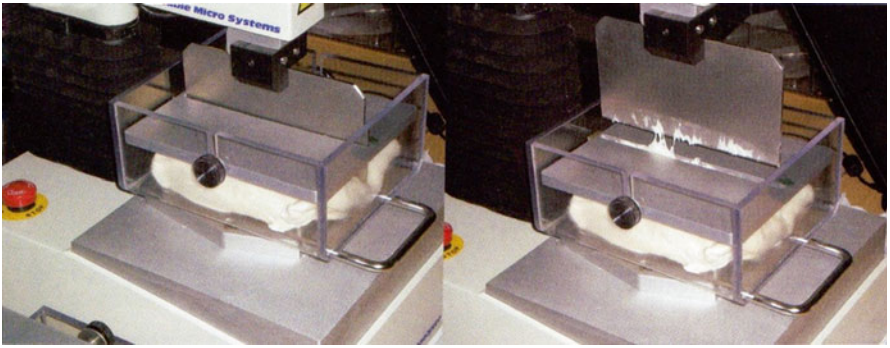

Fig. 2.1 Dough stickiness test (Courtesy *BakeTran*)

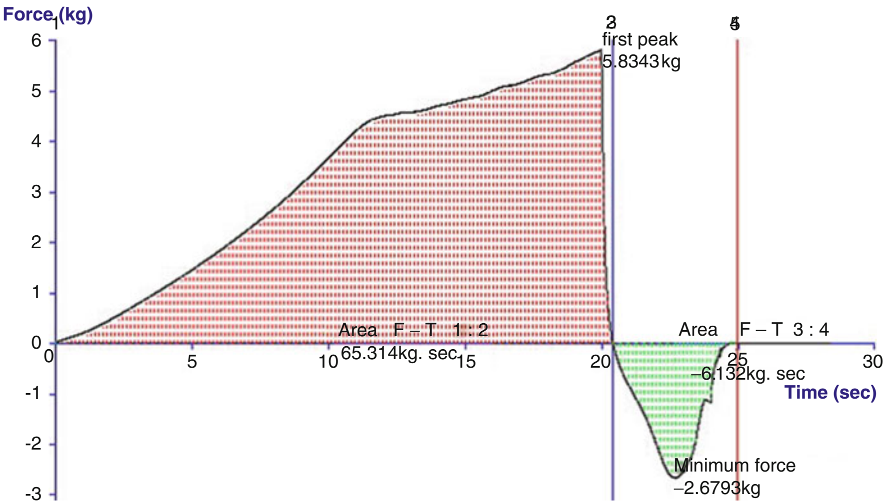

Fig. 2.2 Typical output from the dough stickiness test (Courtesy *BakeTran*)

to achieve. The recent introduction of a new stickiness test (Cauvain 2012) may help better understand what contributes to stickiness in dough (Figs. 2.1 and 2.2).

A common reaction to dough stickiness is to reduce the dough water level in the mixer. While this may improve the handling of the dough it does not necessarily reduce its overall stickiness by much. Doughs which are under-developed are more prone to the effects of shear, and optimised water levels are an important part of delivering optimized dough development. In addition, lower water (stiff) doughs tend to have a greater resistance to deformation and a tendency to be more elastic. This often means that greater pressures need to be applied during dough processing during moulding and can lead to the damage of gas bubble structures in the dough which show in the final product as areas of coarse structure, or even unwanted large holes in the crumb (Cauvain and Young 2008).

In practical doughmaking and dough handling the distinction between one physical property and another is often hard to make because of the interaction of the dough with processing methods, such as moulding, as will be discussed in Chap. 4. During processing the dough is subjected to different magnitudes of force and those forces are applied at different rates. At the same time the dough is subject to physical change as a result of chemical actions at the molecular level, along with further effects from the physical forces associated with gas production.

We can therefore see dough development as being the modification of some very important physical properties of bread doughs which make major contributions to the character of the final product. This modification of gluten structure can be achieved by a number of different physical and chemical processes, and various combinations of these form the basis of the different groups of breadmaking processes which are in common use.

Most of the desirable changes resulting from 'optimum' dough development, whatever the breadmaking process, are related to the ability of the dough to retain gas bubbles (air) and permit the uniform expansion of the dough piece under the influence of carbon dioxide gas from yeast fermentation during proof and the early stages of baking. The creation of dough with a more extensible character is especially important for improved gas retention, while reductions in dough resistance and elasticity play a major role in the modification of bubble structures during processing, as will be discussed in more detail for some of the breadmaking process groups described below.

It is important to distinguish between gas production and gas retention in fermented doughs. Gas production refers to the generation of carbon dioxide gas as a natural consequence of yeast fermentation. Provided the yeast cells in the dough remain viable (alive) and sufficient substrate (food) for the yeast is available, then gas production will continue, but expansion of the dough can only occur if that carbon dioxide gas is retained in the dough. Not all of the gas generated during processing, proof and baking will be retained within the dough before it finally sets in the oven. The proportion that will be retained depends on the development of a suitable gluten matrix within which the expanding gas can be held. Gas retention in dough is therefore closely linked with the degree of dough development which occurs, and as such will be affected by a large number of ingredients and processing parameters which are not necessarily independent of one another.

A further distinction should be made between dough development and gas retention and the factors which affect both. Dough development is a poorly-defined term used by bakers to indicate when they believe that the dough has all of the necessary physico-chemical properties it needs to deliver the required bread characteristics. This precise combination of properties varies with the breadmaking method employed, the equipment and the product type but is essentially based on the development and modification of the gluten network in the dough. Since gluten is the essential 'ingredient' in achieving the required dough development it follows that flour is the primary 'building block' in that process. Improved dough development leads to improved gas retention which is manifest through increased bread volume, crumb softness and changes in crumb structure and texture.

The ingredient and process interactions which affect the formation of the gluten network in the dough will be discussed in detail in the following sections and chapters. It is recognised that the addition of many ingredients will impact on the gas retention properties of the dough and lead to increased product volume (and softness). However, not all of the additions which improve dough gas retention impact on product cell structure and this is because some of them do not make a direct contribution to dough development. Studies by Miller et al. (2005) of dough mixing using near infrared (NIR) technologies have shown no changes in NIR 'optimum' mixing (dough development) time with changing levels of ingredients such as emulsifiers and enzymes. The precise relationship between dough development and gas retention is not clear but it is clearly wrong to assume that all improvements in gas retention are the direct result of improvements in dough development.

Cell Creation and Control

The production of a defined cellular structure in the baked bread depends entirely on the creation and retention of gas bubbles in the dough. After mixing has been completed, the only 'new' gas which becomes available is the carbon dioxide gas generated by the yeast fermentation. Carbon dioxide gas has many special properties and at this point we are concerned with two: its high solubility by comparison with the other major gases in breadmaking, nitrogen and oxygen and its relative inability to form gas bubbles in dough. As the yeast produces carbon dioxide gas, the latter goes into solution in the aqueous phase within the dough. Eventually the solution becomes saturated and unable to hold any further carbon dioxide which may be produced. The rate at which saturation occurs depends on the fermentation conditions, but is fairly fast in all breadmaking processes, as shown by rapid dough expansion as the gas is retained within the developing or developed dough structure.

If the carbon dioxide does not form its own gas bubbles how then does expansion of the dough through gas retention occur? Two other gases are available in significant quantities within the dough as a result of mixing, oxygen and nitrogen, both of which are derived from any quantities of air trapped within the dough matrix as it forms. In the case of oxygen, its residence time within the dough is relatively short since it is quickly used up by the yeast cells within the dough (Chamberlain 1979; Chamberlain and Collins 1979). Indeed so successful is yeast at scavenging oxygen that in some breadmaking processes no oxygen remains in the dough by the end of the mixing cycle. The rapid loss of oxygen from mechanically developed doughs has been illustrated previously for a wide range of nitrogen to oxygen ratios (Collins 1985).

With the removal of oxygen from the dough, the only gas which remains entrapped is nitrogen and this plays a major role by providing bubble nuclei into which the carbon dioxide gas can diffuse as the latter comes out of solution. The number and sizes of gas bubbles available in the dough at the end of mixing will be strongly influenced by the mechanism of dough formations the mixing conditions in a particular machine and its design. The influence of mixing action in each of the breadmaking processes will be further discussed below and the effects of mixer design in Chap. 4. At this stage it is only necessary to register the significant role that mixing will play in the creation of dough bubble structures for subsequent expansion.

It is now clear that for most breadmaking processes, particularly those which do not include a bulk dough resting time, the finest cell structure we can form is already in the dough by the end of the mixing process (Cauvain and Collins 1995). During the processing stages subsequent to mixing some modification of the bubble structure does occur which essentially comprises an expansion of the bubbles already created (Whitworth and Alava 1999). The modification of bubble structures in the dough after mixing depends to a significant extent on the rheological qualities of the dough and we will be concerned with three of the rheological properties described earlier.

Major Breadmaking Process Groups

The sequences required for a complete breadmaking process have been briefly described above. The processing stages which occur after dividing the bulk of the dough, such as shaping, proving and baking, are largely common to all breadmaking processes, and so when we discuss the different breadmaking processes we are mainly concerned with the methods which are used to produce the developed bulk dough ready for dividing and further processing. In discussing the different processing methodologies we will also recognize the important contribution that different ingredient qualities and formulations play in determining dough development within a particular breadmaking process.

The methods by which dough development is achieved in the bakery may be fitted into four broad processing groups, although there are numerous variations and also elements of overlap between each of the individual groups. For discussion purposes we can name and characterize the groups as follows:

- *Straight dough bulk fermentation*, where resting periods (floor-time) for the dough in bulk after mixing and before dividing are the norm. For the purposes of discussion in this chapter, a minimum bulk resting period of 1 h will be required for a process to fit into this category.
- *Sponge and dough*, where a part of the dough formulation receives a prolonged fermentation period before being added back to the remainder of the ingredients for further mixing to form the final dough, which is then commonly processed without further delay.
- *Rapid processing*, where either a very short (<1 h) or no period of bulk fermentation is given to the dough after mixing and before dividing.
- *Mechanical dough development*, where a primary function of mixing is to impart significant and often measured quantities of energy to facilitate dough development, and the dough moves without delay from mixer to divider for further processing.

Delayed addition of salt. While strictly not a defined breadmaking process because it could be used with any of the four processes described above, some bakers may delay the addition of salt until the later stages of mixing. The objective is to permit full hydration of the proteins in the flour and the optimisation of the gluten structure in the dough before the water-binding effects of salt (sodium chloride) are introduced. The salt is readily soluble in the dough and quickly disperses. However, the technique is most applicable to low speed mixing and with mixers which allow ready access to the dough during processing. Dosing salt late in short-time, high speed mixing processes (e.g. Mechanical Dough Development) present practical problems though technically it could be arranged. The lack of inhibiting effect on the yeast by delaying salt addition is not commonly a problem because the delayed salt method is most commonly employed in breadmaking processes where the dough is rested after mixing and before dividing. The dough may have slightly more gas present by the end of the resting period but the impact will be small.

Each of the process groups identified above has a similar equipment requirement in that they all need some means of mixing the ingredients together to form a cohesive dough. The nature of that mixing equipment will make an important contribution to dough development and so it is inevitable that in discussing the individual groups some consideration has to be given to the type of equipment used. To some extent, individual breadmaking processes have become synonymous with different mixers but in many cases that relationship is not absolute since several different mixer types may be capable of exploiting the principles of the same breadmaking process. The suitability of different mixers is most limited in the case of mechanical dough development processes where high mixing speeds and control of the atmosphere during the mixing cycle become very important in achieving the desired bread character (Cauvain and Young 2006).

In commercial practice a close link has also developed between the type of breadmaking process and the scale of manufacture. Once again this link is not absolute with any of the breadmaking process groups being capable of exploitation by bakers of any size. Some breadmaking processes are more sensitive than others to variations in processing conditions, such as time and temperature, and consequently there has been a tendency in smaller-scale bakeries, where greater process flexibility is required, to use the more tolerant and less process sensitive of the breadmaking processes.

Polarization of products to different breadmaking methods has also tended to occur, in part because of the choices of equipment made by bakers, especially at the smaller end of the production scale. In seeking to use breadmaking methods in combination with equipment which give increased flexibility and ‘tolerance’ during processing some bakers have limited their options with regard to the range of bread qualities which it is possible for them to make. At the other end of the scale plant production has also tended to limit its options, although in this case it is because bakers have sought efficiencies of scale and close process control. In some cases, limited appreciation of the critical factors which affect bread quality for a particular process has resulted in particular bread types which have become synonymous with particular breadmaking processes. It is certainly true that not all of the breadmaking processes are equally capable of making optimum quality-bread over the full range of bread types we encounter, but often the possible range of qualities is greater than is appreciated or indeed exploited for any particular process.

It is a mute question as to whether the qualities of the flours which are available determine the breadmaking process to be used or whether the process to be used determines the flour qualities required. In fact, whichever way we answer the question we are correct. As breadmaking processes developed around the world, the 'strength' of the locally available flour had to be accommodated, but as our knowledge of the breadmaking process has increased we have come to learn that there are many different ways of achieving a particular bread quality, and in doing so we have learned that flour quality can be adjusted to achieve our desired aims. In modern breadmaking it is certainly true that the 'best' (usually taken to mean the strongest, the highest protein quantity or quality) wheats will make the 'best' flour for a given process. As we shall see, factors such as bread volume will increase with increasing protein content, but the price we may have to pay with such stronger flours is the adjustment of our preferred processing method. In some cases where we have a fixed processing method, we may not be able to accommodate 'improvements' in flour quality. This close relationship between flour properties and processing methods will be expanded upon in discussion of the individual processing method groups which follows.

Straight Dough Bulk Fermentation

For many, the application of bulk fermentation for dough development is probably the most traditional and most 'natural' of the breadmaking processes. This process group is the most homogenous of all the groups we shall be discussing since the variations within it tend to be confined to different periods of bulk fermentation time, with variations in some other aspects of controlling fermentation, such as those associated with temperature or yeast level. There are only a few essential features of bulk fermentation processes and can be summed up as follows:

- mixing of the ingredients to form an homogeneous dough;
- resting of the dough so formed in bulk for a prescribed time (floor-time), depending on flour quality, yeast level, dough temperature and the bread variety being produced;
- part-way through the prescribed bulk fermentation period there may be a remixing of the dough (a 'knock-back' or 'punching down').

Dough formation for bulk fermentation is usually a low-speed affair carried out by hand or with low-speed mixing machines. Whether mixed by hand or by machine, the amount of energy which is imparted to the dough is very small by comparison with that experienced in other types of breadmaking processes. This is an important distinction because it shows that dough development is almost completely limited to that achieved in the fermentation period. This being the case, control of the factors which affect the bulk fermentation period and the quality of the ingredients used is especially important for optimum bread quality. The formulations for bulk fermentation need only contain a few ingredients as shown in Table 2.1.

Table 2.1 Recipes for bulk fermented doughs

	3 h (%)	1 h (%)
Flour	100	100
Yeast	1	2
Salt	2	2
Water	57	58

Yeast Level

The differences in yeast levels in the two examples of recipes given in Table 2.1 occur because more yeast is required with shorter bulk fermentation periods in order to achieve full dough development in the shorter time. This relationship between dough development time and yeast level probably comes from the contribution that enzymes present in the yeast cells, viable or dead, make to modification of the protein structures which are forming with increasing dough resting time. Of the enzymes present, the proteolytic enzymes and the natural reducing agent glutathione are likely to play the major roles. Flour too contains enzymes which can contribute to dough development.

If we take this relationship between yeast and bulk resting time to its ultimate conclusion we could continue to increase the yeast level and expect to eliminate bulk time altogether. Indeed it is possible to make a 'no-time' dough in this manner, but the resulting bread will be somewhat poorer in quality than we might expect from 1 or more hours of bulk time. This no-time doughmaking approach has been used by bakers and is often referred to as an 'emergency dough' to be made when there is insufficient time available to allow for a bulk rest of the dough (Ford 1975). We can see then that while there is a working relationship between yeast level and bulk time the passage of a period of time is still very important for gluten modification and the production of suitable bread quality to occur, whatever the level of yeast added. For practical purposes a period of at least 1 h in bulk should be given to the dough.

Since the mechanism for dough development in bulk fermentation depends to a significant degree on yeast activity, we can also reasonably expect dough temperature to play a major role in determining the time at which full development is achieved for a recipe with a given yeast level. This is certainly the case and in bulk-fermented doughs it is normal to adjust the yeast level, or bulk time, or both, with changes in dough temperature, whether the latter is deliberately introduced or occurs from some unintentional source. There are no 'hard or fast' rules for temperatures in the bulk dough at the end of mixing, but conventional practice places final dough temperatures in the region of 21–27 °C (70–80 °F). As a 'rule of thumb' a 4 °C rise in dough temperature can be offset by a reduction in yeast level by one-half. Conversely a 4 °C fall in dough temperature requires a doubling in added yeast. The practising baker will be familiar with such relationships and may make appropriate adjustments with rises and falls in ambient bakery temperatures in those countries which experience significant changes in daily and seasonal temperatures. In the context of dough temperature control Calvel et al. (2001) considered that the control of the final dough temperature was one of the most significant factors in achieving consistent bread quality using fermentation systems.

Flours

The 'strength' of the flour which can be used in bulk-fermented doughs is closely linked with the length of the bulk fermentation period which we employ. In general, the stronger the flour, the longer the fermentation period we will require in order to achieve optimum dough development (Fig. 2.3), and the better the final bread quality will be (i.e. with a larger volume, finer crumb structure and softer crumb). Flour strength is largely related to its protein content and quality, as will be discussed in Chap. 12, so that higher protein flours require longer bulk fermentation times than lower protein flours to deliver optimum bread quality. The level to which bran is present in the flour will also affect the length of bulk fermentation times, with wholemeal (wholewheat) flours requiring shorter bulk time than white flours. A typical white flour protein content for bulk fermentation would be 12 % (14 % moisture) or greater.

Failure to match flour and bulk times will result in a number of quality defects in both the dough and the baked product. In the dough insufficient bulk time gives one which is 'under-fermented' or 'green'/unripe and will exhibit a tough, rubbery gluten, not easily given to being moulded and which, in turn, will yield loaves of small volume, dense cell structure and firm crumb. Too long a bulk time will result in the dough becoming 'over-fermented', readily giving up its gas at the slightest touch

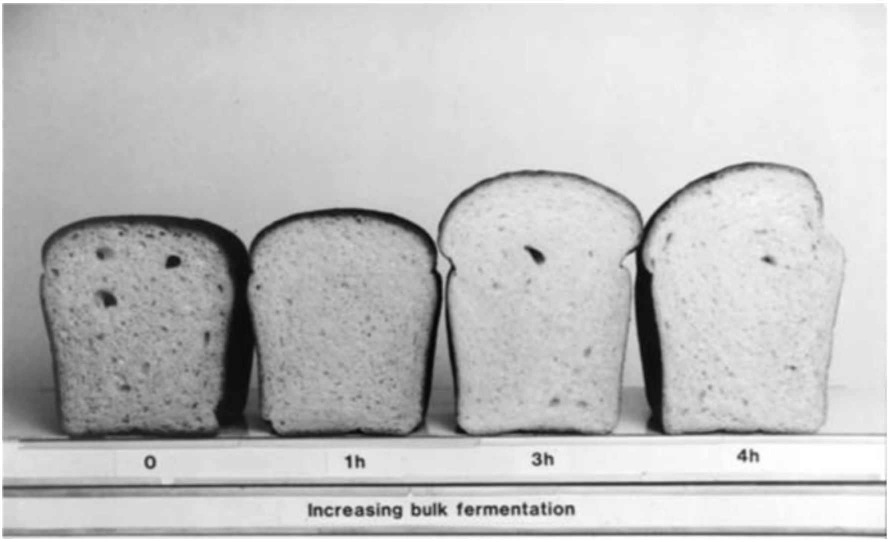

Fig. 2.3 Effect of bulk fermentation time on bread quality

and liable to collapse under its own weight. If bread be made from such a dough it is likely to have a poor shape, although with adequate volume, and an irregular cell structure, frequently with large holes. In part, these changes occur because there is a progressive change in the physical properties in the gluten in the dough. Commonly referred to as 'relaxation', the changes are usually a loss of resistance to deformation and elasticity which is accompanied by an increase in extensibility.

The supplementation of flours with dried, vital wheat gluten to raise the protein content of weaker base flours is a common practice in many parts of the world (Chamberlain 1984; Cauvain 2003). While such an approach works well in some breadmaking processes, gluten supplementation is less successful where mixing methods are of the lower speed, less intense form. This is sometimes the case in the production of bulk-fermented doughs and, even though a long resting period is available, the conditions are not suited to continuing gluten development. Some additional gluten development may be gained during remixing at knock-back but generally flours with higher levels of gluten supplementation do not perform as well as flours which contain the same level of indigenous protein.

Flours to be used for bulk fermentation processes are usually low in cereal *alpha-amylase* (high Falling Number) and will only be supplemented with low levels of fungal *alpha*-amylase or malt flour, if at all, because of the potential softening effects on the dough handling character with extended bulk resting time.

Water Levels

One of the most obvious manifestations of the changes taking place when the dough ferments in bulk is a progressive softening of the dough with increasing time. In breadmaking, bakers aim to achieve a 'standard' dough consistency for dividing and moulding. They accomplish this by adjusting the water level added during dough mixing according to the water absorption capacity of the flour (Chap. 12). During bulk fermentation progressive enzymic action is responsible for the softening of the dough which occurs. Since enzymic actions are time and temperature dependent, we can reasonably expect that dough softening will vary according to the bulk fermentation conditions, and in these circumstances adjustment of added water levels will have to be made to compensate for these changes. The recipes given in Table 2.1 show how a reduction in added water is required with longer bulk fermentation times in order to maintain a standard dough consistency for dividing.

Optional Ingredients

While the only essential ingredients required are those given in Table 2.1, other ingredients are sometimes added for making bread by bulk fermentation. Typical rates of addition for these optional ingredients and the properties they confer to the

Table 2.2 Optional ingredients in bulk fermentation

	Percentage of flour weight	Improvement
Fat	1.0–2.0	Gas retention
		Crumb softness
Emulsifiers	0.1–0.3	Gas retention
		Crumb softness
Enzyme-active malt flour	0.1–0.2	Gas production
		Gas retention
		Crust colour
Enzyme-active soya flour	0.2–0.5	Crumb whiteness
Skimmed milk powders	Up to 2.0	Crust colour
		Flavour

dough and the bread are given in Table 2.2. In addition to those optional ingredients identified in Table 2.2, 'improvers' may be added to bulk-fermented doughs. Usually the levels of addition are much lower than would be seen in no-time doughmaking processes. In some cases the 'improver' may consist of a small quantity of an oxidizing material added at the flour mill in order to assist in dough development (Chaps. 3 and 12). Various flour treatment agents are permitted for use around the world, although the numbers are becoming fewer. Supplementation with enzymes may also occur.

Process Variations

Reference has already been made to one process variation which may be encountered in bulk fermentation processes, namely the operation of 'knocking-back', 'punching down' or remixing the dough part way through the fermentation time. This operation tends to happen with doughs which are undergoing longer fermentation periods, greater than 1 h. A number of advantages are claimed for the operation, including equilibration of dough temperatures throughout its bulk and the incorporation of more air into the dough to improve yeast activity.

Other variations include the delaying of the addition of salt and yeast to the latter stages of mixing or, indeed, the later stages of bulk fermentation. Delaying the addition of these ingredients changes the manner and degree of the dough development process. For example, delaying the addition of salt until about two-thirds of the way through the bulk period increases the effects of fermentation without having to increase the bulk fermentation period. One of the common claims for delaying the addition of such ingredients is for the modification of flavours in the dough (Calvel 2001). The development of bread flavour has already been discussed in Chap. 1.

Creation of Bubble Structure

The basic elements of bubble structure creation have been described earlier in this chapter. As with all breadmaking processes, the gas bubbles in the dough at the end of mixing exhibit a range of sizes from a few μm to several mm. During the bulk fermentation period the evolution of carbon dioxide gas leads to the expansion of many of these bubbles. At the same time that the bubbles are being expanded, changes in the dough rheology are occurring which make it less resistant to deformation. Because of such changes it is possible to collapse many of the larger bubbles in the dough during the knock-back or moulding stages which leaves the many smaller bubbles which are subsequently inflated by more carbon dioxide gas. Baker and Mize (1941) showed this to be the case for bulk-fermented doughs and considered that such events were major contributors to the formation of fine and uniform cell structure in bread made from bulk-fermented doughs. In the past, when bulk fermentation was the norm, craft bakers advocated the modification of bread cell structure using this principle of inflation, collapse, creation (more likely retention) of small bubbles and re-inflation for the production of so-called ‘competition breads’ with a finer and more uniform cell structure (Horspool and Geary 1985). Often the technique required that dough pieces be passed back and forth through the sheeting rolls of a pastry brake. Thus the creation of bread cell structures from bulk-fermented doughs clearly owes much to the manipulation of the dough during processing. This is not the case with no-time doughmaking processes as will be discussed below and in later chapters.

Sponge and Dough

Elements of sponge and dough processes are similar to those for bulk fermentation in that a prolonged period of fermentation is required to effect physical and chemical changes in the dough. In sponge and dough this is achieved by the thorough fermentation of part of the ingredients rather than all of them. The length of sponge fermentation times may vary considerably, as may the composition of the sponge. In some cases the sponge component may be replaced with a flour brew in which the proportion of liquid is much higher than that used in a sponge.

The key features of sponge and dough processes are:

- a two-stage process in which part of the total quantity of flour, water and other ingredients from the formulation are mixed to form an homogeneous soft dough—the sponge;
- resting of the sponge so formed, in bulk for a prescribed time (floor-time) and under defined temperature conditions, mainly depending on flavour requirements;
- mixing of the sponge with the remainder of the ingredients to form an homogenous dough;
- immediate processing of the final dough, although a short period of bulk fermentation period may be given.

In the UK, sponge and dough formation tends to be a low-speed process carried out with low-speed mixing machines, while in North America more intense mixing is given to the sponge and the subsequent dough. On a small scale the mixer used to form the sponge may also provide the container in which to store it, provided it is not required for other uses. In large-scale production of sponges, separate containers which can be moved to temperature-controlled environments are needed in order to ensure uniformity of sponge development and to achieve the required scales of manufacture.

Roles of the Sponge

The main roles of the sponge are to modify the flavour and to contribute to the development of the final dough through the modification of its rheological properties. The process of flavour development in the sponge, though complex, is manifested in a relatively straightforward manner with an increase in the acidic flavour notes arising from the fermentation by the added yeast and other microorganisms naturally present in the flour (usually lactic acid bacteria). To maintain the right flavour profile in the finished product, the sponge fermentation conditions should be closely controlled and care should be taken to avoid a build-up of unwanted flavours by thorough cleaning of storage containers after use.

During the sponge fermentation period there will be a decided decrease in sponge pH with increasing fermentation (whether arising from changes in time, temperature, or both). It should be noted that the degree to which sponge pH can be lowered may well be affected by the source of the wheat flour. This is especially the case in countries like the UK where the mandatory addition of chalk to the flour in the mill limits the drop in the pH because of the buffering effect of calcium carbonate. The rheological character of the gluten formed during the initial sponge mixing will change, with the sponge becoming very soft and losing much of its elasticity. As standing time increases the condition of the sponge increasingly resembles an over-fermented dough. The low pH of the sponge and its unique rheological character are carried through to the dough where they have the effect of producing a softer and more extensible gluten network after the second mixing. In many cases the addition of the sponge changes the rheological character of the final dough sufficiently to render further bulk resting time unnecessary, so that dividing and moulding can proceed without further delay.

Formulations

The main requirement for sponge and dough processes is to decide what proportion of the total flour is to be used in the production of the sponge. This proportion will vary according to individual taste and location. Two examples are given in Table 2.3,

Table 2.3 Examples of sponge and dough formulations (ingredient proportions expressed as percentage total flour weight)

	Sponge	Dough
UK 16 h sponge		
Flour	25.0	75.0
Yeast	0.18	1.75
Salt	0.25	1.75
Water	14.0	43.0
Fat	0.0	1.0
North American 4 h sponge		
Flour	65.0	35.0
Yeast	2.4	0.0
Salt	0.0	2.3
Water	40.0	25.0
Improver	0.1	0.0
Milk solids	0.0	3.0
Sugar	0.0	6.0
Fat	0.0	3.0

one for a typical 16 h (overnight) sponge in the UK and the other a 4 h example from North America. The contrast in the approaches is very evident.

Improvers

Additions of improvers are not essential to the production of bread by sponge and dough methods since a contribution towards dough development is made directly by the sponge. However, as shown by the example of a North American recipe in Table 2.3, improver additions are common in some variations of the process. The choice of improver type and the timing of the addition, whether to the sponge or the dough, depend to a large extent on the bread variant being produced and traditional practices.

There will be different potential effects from the different oxidizing agents present if the improver is added to the sponge side of the process. Late-acting oxidizing agents have little or no effect until the dough reaches the prover (proofer) while faster-acting oxidizers, such as ascorbic acid and azodicarbonamide will act in the sponge mixing stage. In the case of ascorbic acid, oxygen is required for oxidation of the dough proteins to occur (Collins 1994). Within the sponge the atmosphere will quickly become anaerobic and so opportunities exist for the ascorbic acid in particular to act as a reducing agent, its true chemical form, and to modify (weaken) gluten structures. The opportunities for enzymic action from the improver should also be considered, so that all in all there is a strong case for restricting improver additions to the dough side of the process where control of the changes which may occur is more readily achievable.

Flours and Other Ingredients

Flours used in typical sponge and dough production will be at least as strong as those used in bulk-fermented doughs with protein contents not less than 12 % (14 % moisture). As with bulk-fermented doughs, flours for sponge and dough tend to have high Falling Numbers. High *alpha*-amylase activity could be a problem in the sponge, but is less likely to be a problem in the dough since the latter rarely has any floor-time after mixing.

Process Variations

The most obvious of process variations encountered with sponge and dough systems will be variations in the sponge fermentation times. These will vary according to individual requirements for efficient processing, flavour development and available raw materials. Sponge temperatures will vary but are usually kept to maximum of 21 °C (70 °F). Final dough temperatures will fall into a similar range to those used in bulk fermentation, between 21 and 27 °C (70–80 °F).

In some cases the sponge may be incorporated into a dough which is then given a period of bulk fermentation or it may be added to doughs which are to be developed by a rapid processing method or by the Chorleywood Breadmaking Process (CBP), as will be discussed below. Since a primary function of a sponge is to develop bread flavour, alternative liquid brew or ferment systems have developed to fulfill this function. In most cases there will be little or no dough development function from the brew, other than that which comes from the ingredients. The application of liquid brews to the production of hamburger buns is described in Chap. 9.

Rapid Processing

This heading covers a multitude of slightly different breadmaking systems, each of which has evolved based on different combinations of active ingredients and processing methods. A common element to all breadmaking processes covered under this heading will be the inclusion of improvers to assist in dough development and the reduction of any individual fermentation period, in bulk or as divided pieces (but not including proof) to less than 1 h. Processes which are covered by this heading include activated dough development, no-time doughs with spiral mixers and the Dutch green dough process.

Activated Dough Development (ADD)

This process was developed in the USA during the early 1960s (Brown 1993) and became popular in smaller bakeries in the USA and the UK thereafter. Its essential features were:

- the addition of a reducing agent, usually; L-cysteine hydrochloride
- the addition of oxidizing agents;
- the addition of a fat or an emulsifier;
- extra water in the dough to compensate for the lack of natural softening;
- extra yeast to maintain normal proving times.

Since its first introduction ADD has undergone a number of changes and now seldom exists in its 'classic' form. When ADD was first introduced, potassium bromate was a common component in the added improver, together with ascorbic acid and L-cysteine hydrochloride. The increasing expense of L-cysteine hydrochloride and the withdrawal of potassium bromate from many permitted lists of breadmaking ingredients have both played a role in the demise of ADD certainly in the UK and elsewhere.

Since the dough development process in ADD was mostly chemically induced, low-speed mixers could be employed. This allowed craft bakers to continue using their existing low-speed mixers and eliminate bulk fermentation without purchasing high-speed mixers being developed for mechanical dough development processes in the 1950s and 1960s. With the passage of time many of the smaller bakers changed to spiral-type mixers which allowed them to move to improver formulations with fewer 'chemicals' at a time when consumer attitudes to 'additives' were changing.

A short period of bulk fermentation (typically less than 30 min) before dividing was beneficial for ADD product quality. Sponges could be added to change bread flavour if required. Final dough temperatures were in the region of 25–27 °C (76–80 °F).

No-Time Dough with Spiral Mixers

In many bakeries, especially the smaller ones, the spiral mixer has taken over as the main type of mixer being used. Spiral mixers have a number of advantages for no-time doughmaking processes in smaller bakeries or where fine cell structures are not required in the baked product. These will be discussed in more detail in Chap. 4 but it is worth noting at this stage the input of higher work levels than those used with traditional low-speed mixers, with accompanying reductions of mixing times to achieve optimum dough development.

Although mainly used for no-time doughs some bakers will use short periods of bulk fermentation, usually 20–30 min, to assist with dough development after mixing. In these circumstances the control of final dough temperature is important in order to both control and optimize dough development. The additional gas generated during such bulk resting periods will place greater demands on divider weight control and yield products with a more open cell structure. Flavour development in the crumb is likely to be limited given the short time periods which are commonly used.

Some spiral mixers impart sufficient energy to raise dough temperatures above that expected from the ingredients. Final dough temperatures vary widely for no-time doughs with spiral mixers, and practical examples may be found from 21 °C (or lower e.g. for frozen doughs), to 27 °C (70–80 °F). For many bakers the advantage of using lower dough temperatures lies in restricting yeast activity which comes with the usually higher levels of added yeast. A counter to this advantage is the reduction in chemical and enzymic activity which will occur at lower dough temperatures with a subsequent reduction in overall dough development.

The Dutch Green Dough Process

This process was developed in the Netherlands, hence its name. It is included under this process group heading since the mixed dough passes without delay to dividing, although significant periods of resting are involved in the total process. The essential features of the process are:

- mixing in a spiral-type mixer or extra mixing in a speeded-up conventional low-speed mixer;
- the dough is divided immediately after mixing;
- the divided dough is rounded and given a resting period of the order of 35–40 min;
- the dough is re-rounded and given a further resting period before final moulding.

The basis of the name ‘green’ refers to the fact that after the mixing the dough is considered to be underdeveloped or ‘green’ in classic bakery parlance. Dough development continues in the resting periods after each rounding. When first introduced, two or three resting periods were used; now it is more common to see one or, to a lesser extent, two.

Role of Improvers and Other Ingredients in Rapid Processing

Although it is possible to make no-time doughs without additional ingredients, such as with the traditional Dutch green dough process, it is common for improvers to be added to assist with dough development in the absence of bulk fermentation time.

The compositions of improvers which are used vary widely, although the most common ingredients are ascorbic acid, enzyme-active materials and emulsifiers. The degree of oxidation gained from the ascorbic acid depends in part on the level used and in part on the mixing machine and its ability to occlude air during the mixing operation. This latter aspect is discussed in more detail in Chap. 4.

Most no-time dough processes use flours of the stronger type with protein contents of 12 % (14 % moisture basis) or more. Since there is no appreciable softening of the dough from fermentation before dividing, water additions will be higher than in bulk fermentation. The precise water level used will also be influenced by the type of mixer, with some doughs being softer and stickier when taken out of one machine compared with another. Often this initial stickiness is lost in the first few minutes after leaving the machine. The cause of this phenomenon is not clear but may well involve the quantity of gas remaining in the dough at the end of mixing (see below).

Mechanical Dough Development

The common elements of this group are that there is no fermentation period in bulk and dough development is largely, if not entirely, achieved in the mixing machine. In mechanical dough development the changes brought about by bulk fermentation periods are achieved in the mixer through the addition of improvers, extra water and a significant planned level of mechanical energy.

The principle of mechanical dough development were exploited in the 1950s by the Wallace and Tiernan 'Do-maker' (Williams 1975). The loaf coming from the 'Do-maker' had a characteristically fine and uniform cell structure which eventually proved to be unpopular with many consumers, and today few installations remain in use. The 'Do-maker' used a continuous mixer and separate developer chamber. Other processes which exploited the same principles of mechanical dough development and continuous mixing included the Henry Simon-Strahmann plant, the Amflow process and the Oakes Special Bread Process. Like the 'Do-maker', few installations remain in use though interest in the applications of continuous dough mixing has again increased in recent years (see Chap. 3).

In 1958 the British Baking Industries Research Association at Chorleywood, UK (later merged into the Flour Milling and Baking Research Association and more recently into the Campden & Chorleywood Food Research Association) began to investigate the important factors in the mechanical development of dough. The work was to lead to the one mechanical dough development process which has stood the test of time—the Chorleywood Breadmaking Process (CBP) (Cauvain and Young 2006)—and this process will serve as the basis for discussing and understanding the key issues in mechanical dough development. More detailed discussion of the CBP-compatible mixing equipment and its functions are contained in Chap. 4.

Chorleywood Bread Process (CBP)

The basic principles involved in the production of bread and fermented goods by the CBP remain the same as those first published by the Chorleywood team in 1961, although the practices have changed with changes in ingredients and mixing equipment (Cauvain and Young 2006). The essential features of the CBP are:

- mixing and dough development in a single operation lasting between 2 and 5 min at a fixed energy input;
- the addition of an oxidizing improver above that added in the flour mill;
- the inclusion of a high melting point fat, emulsifier or fat and emulsifier combination;
- the addition of extra water to adjust dough consistency to be comparable with that from bulk fermentation;
- the addition of extra yeast to maintain final proof times comparable with those obtained with bulk fermentation;
- the control of mixer headspace atmosphere to achieve given bread cell structures.

The main difference between the CBP and bulk fermentation processes lies in the rapid development of the dough in the mixer rather than through a prolonged resting period. The aim of both processes is to modify the protein structure in the dough to improve its ability to stretch and retain gas from yeast fermentation in the prover; in the case of the CBP this is achieved within 5 min of starting the mixing process. The advantages gained by changing from bulk fermentation to the CBP include:

- a reduction in processing time;
- space savings from the elimination of the bowl of dough at different stages of bulk fermentation;
- improved process control and reduced wastage in the event of plant break-downs;
- more consistent product quality;
- financial savings from higher dough yield through the addition of extra water and retention of flour solids which are normally fermented away.

Disadvantages include:

- faster working of the dough and greater process control are required because of the higher dough temperatures used;
- a second mixing will be required for the incorporation of fruit into fruited breads and buns;
- in some views, a reduction of bread crumb flavour because of the shorter processing times.

The last disadvantage listed is one of continual debate which has been constantly fuelled by the detractors of the CBP without any real understanding of the processes by which bread flavour is developed. The basis of bread crumb flavour development was discussed in Chap. 1, and while undoubtedly linked with the length of bulk fermentation time, in these days of predominantly no-time doughs, is probably more likely to be affected by ingredient additions and crust formation. If increased flavour is required in bread crumb made by the CBP, then the use of a sponge or a flour brew is recommended. Bulk fermentation after the completion of dough mixing in the CBP is not recommended because of the adverse changes which occur in the dough and the loss of subsequent bread quality.

Role of energy during mixing. The role that energy plays in optimizing bread quality during mechanical dough development can be readily assessed by comparing the loaves illustrated in Fig. 2.4. As the level of energy per kilogram of dough in the mixer increases, so bread volume increases, and with this comes a reduction in cell size and increased uniformity. With the range of flours studied when the CBP was first introduced into the UK, optimum energy levels quickly became standardized at 11 W-h/kg dough (5 W-h/lb) with little, if any, benefit being gained in varying from that level. Later work in New Zealand (Waters et al. 2013), the USA and the UK was to show that optimum work input varied according to flour characteristics with those derived from 'extra strong' wheats requiring optimum energy inputs above the standard 11 W h/kg. Despite the variation in total energy input, optimum bread quality with such flours in the UK was only gained by increasing the mixing speed in order to continue to deliver the energy within the specified 2–5 min time scale. An example of this relationship is illustrated in Fig. 2.5 for a UK wheat variety.

The role of energy during CBP mixing has yet to be fully explained. It is very likely that the high energy inputs are capable of mechanically breaking the disulphide bonds holding the original protein configurations together since such processes are known to occur in the mechanical modification of other molecules. The effect of mechanical energy might therefore be likened to the effects of natural or chemical reduction and, as such, will increase the sites available for oxidation. Chamberlain (1985) considered that only about 5 % of the available energy was required to break the disulphide bonds with the rest being consumed by mixing of the ingredients and the breaking of weaker hydrogen bonds. The mechanism of dough formation is discussed in more detail in Chap. 11.

The input of energy during mixing causes a considerable temperature rise to occur. Final dough temperatures are higher than those with other breadmaking processes and fall in the region of 27–32 °C (80–90 °F). Some bakers may see this as a

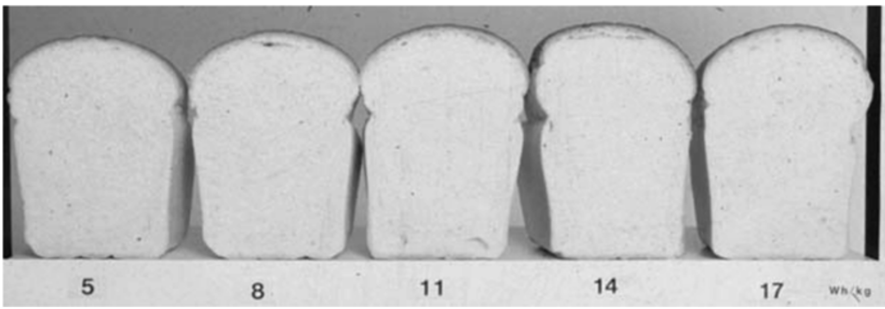

Fig. 2.4 Effect of energy input during mixing

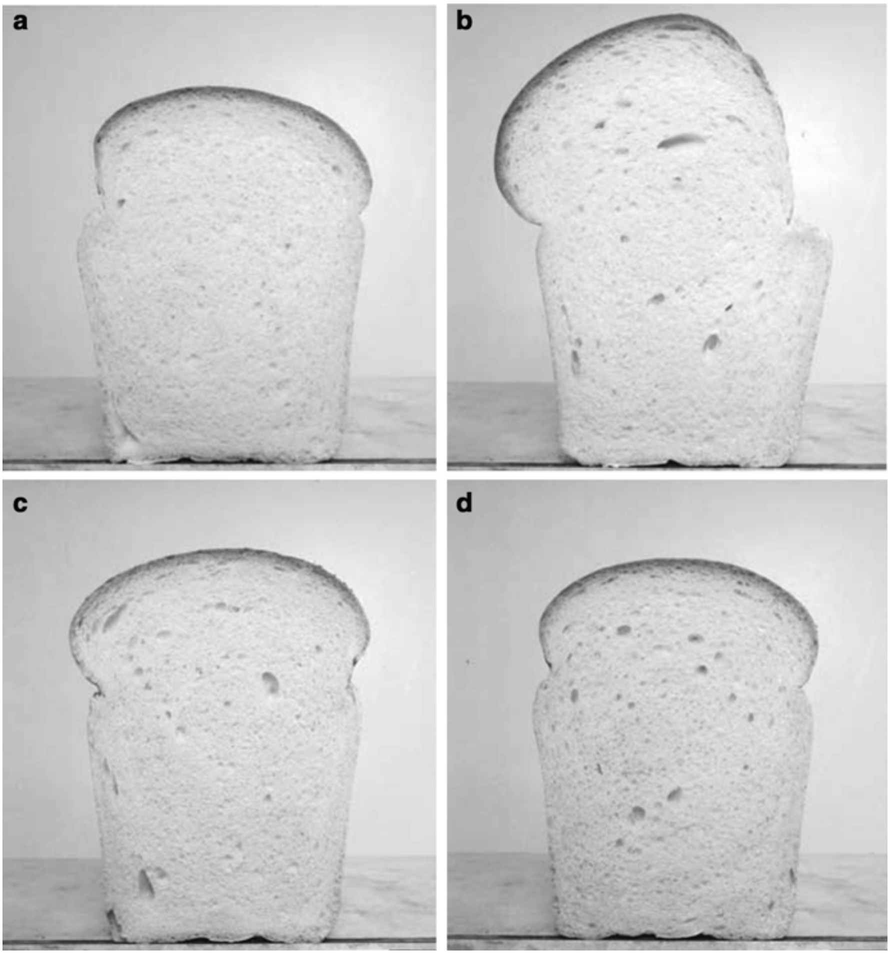

Fig. 2.5 Effect of energy input and mixing speed on bread quality. (**a**) 600 rpm and 5 W h/kg, (**b**) 600 rpm and 17 W h/kg, (**c**) 250 rpm and 5 W h/kg, (**d**) 250 rpm and 17 W h/kg

disadvantage in trying to control yeast activity, but the very short processing times which are used after mixing should not give rise to undue problems in a well-controlled bakery. As with no-time doughs from rapid-processing techniques, the small advantages gained by reducing yeast activity are outweighed by the loss of dough development. Further, the higher dough temperatures give a dough which is more 'relaxed' (has less resistance to deformation) during moulding and is less susceptible to moulder damage of the type which will be discussed in Chap. 4 and has been described elsewhere (Cauvain and Young 2008)

Energy and dough temperature control. The transfer of energy to the dough during mixing causes the final dough temperature to be considerably greater than would be expected from the simple prediction based on the knowledge of the temperatures and quantities of the ingredients used in the recipe. The control of dough temperature is vital if bread quality is to remain consistent.

The most common method for bakers to achieve a consistent final dough temperature is to adjust water temperature according to the temperature of the flour being used. The formula used is:

$$\text{T.water} = (2 \times \text{T.dough}) - \text{T.flour}$$

where the constant 2 is used because water has approximately twice the thermal capacity of flour and the level of added water is approximately half that of the flour weight, and T.dough is the dough temperature required at the end of mixing.

Thus if` T.dough = 25 °C and T.flour = 20 °C then T.water = 30 °C.

This calculation works for hand and low-seed mixing and can be readily adjusted for changes in ambient bakery of equipment temperatures.

Mechanical mixing such as used in Mechanical Dough Development breadmaking or with spiral mixed doughs complicates the relationship because transfer of energy. The formula now becomes:

$$\text{T.water} = 2(\text{T.dough} - \text{T.rise}) - \text{T.flour}$$

where T.rise is the difference between the final dough temperature if the ingredients where simply blended together and the actual temperature achieved in the dough by the end of mixing.

T.rise can be calculated from a few simple experiments starting with ingredients of known temperatures and masses.

For example, in Mechanical Dough Development the energy transferred to the dough during mixing to 11 W h/kg resulted in the final dough temperature being 14 °C higher than predicted from the simple relationship and this value could be used could be substituted in the equation as follows:

$$\text{T.water} = 2(30 - 14) - 20$$

giving a required water temperature of 12 °C.

Because of the strong relationship between the temperature rise experienced by the ingredients in the dough formation process and the energy transferred during mixing it is possible to use the temperature data to ‘cross-check’ the energy balance during mixing. Such calculations are based on the specific heat capacities of the ingredients, their masses and temperatures, and the heat rise during mixing. For mixers running in a ‘steady’ state’, that is the mixer bowl is losing heat to the bakery atmosphere as quickly as it gains it during mixing, the impact of the metal of the mixer bowl is limited. Examples of the method for calculating energy inputs during mixing may be obtained from equipment manufacturers or published literature (e.g. Cauvain and Young 2006).

As mixing time or defined energy input changes then so will the temperature rise experienced by the dough. In practice it is advisable to carry out tests with a range of mixing conditions to cover the likely mixing scenarios. In some cases the temperature of the ingredients (particularly the flour) and the heat rise experienced during mixing are so significant as to require the use of ice. The latent heat required to convert ice to water is significant and has a powerful cooling effect on the dough. However, gluten development depends on the presence of water and so the use of large quantities of ice may restrict the initial hydration of the gluten-forming proteins. The implications of restricting hydration in the early stages of mixing dough by the CBP are not clear but pre-hydration of flour before intense mixing is often considered to be beneficial.

Flour quality. The process of mechanical dough development has been shown to make better use of the flour protein, and in the early stages of the development of the CBP it was quickly recognized that a given bread volume could be achieved with a lower flour protein content in the CBP than with bulk fermentation (Cauvain and Young 2006). This finding indicated that the protein content of flour could be reduced in some circumstances without the loss of key bread characteristics such as volume, crumb structure and crumb softness.

In the CBP, more than with many other breadmaking processes, there are no disadvantages in supplementing the flour with added dried vital wheat gluten. The move to lower protein contents and supplementation of indigenous protein with dried gluten were important factors in the ability of the UK milling industry to reduce the importation of high-protein North American wheats and to attain near self-sufficiency using home-grown or EC-grown wheats.

With mechanical dough development the quality characteristics demanded in the bread will largely dictate the flour specification and it is common for higher protein contents to be used for non-white bread varieties such as wholemeal (wholewheat) and mixed-grain breads where extra ‘support’ is required for the non-functional (in breadmaking terms) bran, grains and seeds (Fig. 2.6).

Creation of bubble structure. In contrast to the situation in bulk-fermented doughs the cell structure in the final bread does not become finer as the result of processing CBP doughs. In the case of CBP doughs, the final bread crumb cell structure is almost exclusively based on an expanded version of that created during the initial mixing process. The cell structure of UK sandwich breads made with dough taken straight from the mixer is contrasted with that which has been through the common processing sequence of rounding, resting and final moulding in Fig. 2.7. The loss of bread volume with the dough taken from the mixer can be attributed to the absence of intermediate proof during processing, an effect which will be discussed in Chap. 4. This illustration confirms work reported by Collins (1983).

The creation of bubble structures in mechanically developed doughs, and indeed for many other no-time processes, depends on the occlusion of air during mixing. The number, sizes and regularity of the gas bubbles depend in part on the mixing action, energy inputs and the control of atmospheric conditions in the mixer headspace. Collins (1983) illustrated how bread cell structure improved (in the sense of becoming finer and more uniform) with increasing energy input up to an optimum level with subsequent deterioration beyond that optimum. He also showed how

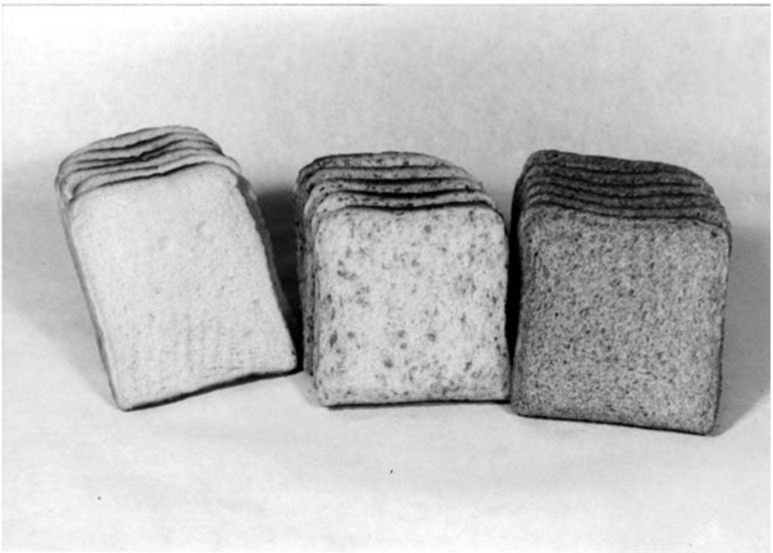

Fig. 2.6 *Left* to *right*, white, mixed grain and wholemeal breads made by the CBP

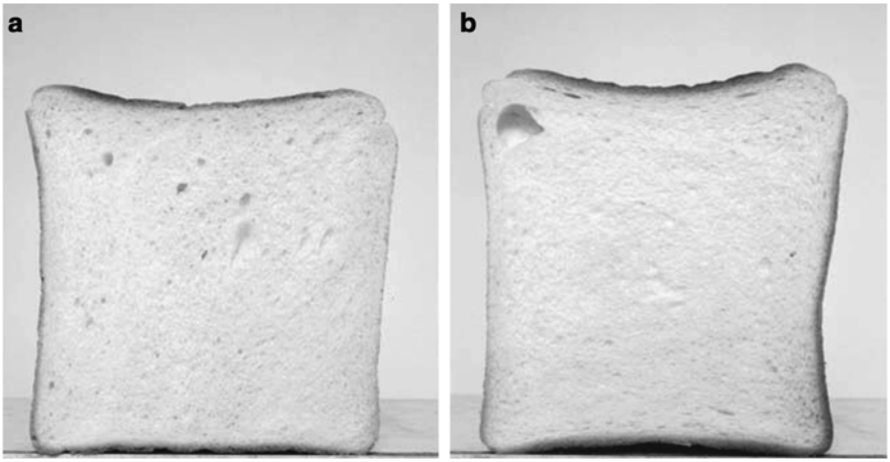

Fig. 2.7 Comparison of bread cell structures from dough (**a**) ex-mixer and (**b**) ex-final moulder

different mechanical mixing actions yielded breads with varying degrees of crumb cell size. Work to measure bubble distributions in CBP bread doughs (Cauvain et al. 1999) has confirmed that different mixing machines do yield different bubble sizes, numbers and distributions. However, in one CBP-compatible mixing machine, variation of impeller design had almost no effect on the bubble population. The lack of differences in the characteristics of the various dough bubble populations was confirmed by the absence of discernible differences in the subsequent bread cell structures.

The modification of bubble populations through the control of atmospheric conditions in the mixer headspace has been known for many years, commonly through the application of partial vacuum to CBP-compatible mixers (Pickles 1968). This control was useful in the creation of the fine and uniform cell structures typically required for UK sandwich breads, but was unsuited to the production of open cell structure breads. In the case of French baguette an open and more random cell structure could be created by extending the intermediate proof time to 20 or 30 min (Collins 1978), provided the delicate dough was given a gentle final moulding in order to preserve the large gas bubbles in the dough.

More recently developed, CBP-compatible mixers are able to work sequentially at pressures above and below atmospheric (Chap. 4). When the dough is mixed under pressure larger quantities of air are occluded, which gives improved ascorbic acid oxidation but more open cell structures. In contrast, crumb cell size becomes smaller as the pressure in the mixer headspace reduces and ascorbic acid oxidation decreases as the pressure decreases. The greater control of dough bubble populations realized in these mixers allows a wide range of bubble structures to be created in the dough. In addition to the fine and uniform structure created from the application of partial vacuum, an open cell structure for baguette and similar products can take place in the mixing bowl by mixing at above atmospheric pressure (Cauvain 1994, 1995). Doughs produced from this type of mixer retain their larger gas bubbles in the dough without significant damage during processing, even when intermediate proof times were shortened from 20 to 6 min.

Dough rheology. Some references have already been made to the importance of dough rheology in breadmaking and there is a detailed discussion of the interactions between the dough and its processing after mixing in Chap. 4. Comment has already been made on the fact that water levels have to be adjusted (upwards) in most no-time doughmaking methods in order to achieve the same dough consistency as would normally be achieved with doughs at the end of a bulk fermentation period. This required dough consistency largely arises because the original designs and functions of many dough processing plants were based on handling bulk-fermented doughs and were not suited to dealing with the firmer doughs yielded from no-time methods when the latter were introduced.

The requirement to add extra water to provide a softer, more machinable dough is particularly true when the doughs are mixed under partial vacuum in the CBP. The lower the pressure during mixing, the ‘drier’ the dough feels and the more water that needs to be added to achieve the same dough consistency as doughs at the end of a bulk fermentation period. This increased dryness with CBP doughs comes in part from the lower volume of gas occluded in the dough at the end of mixing (Chap. 4). If the dough is mixed at pressures greater than atmospheric then the quantity of gas occluded during mixing increases and doughs become softer for a given water level. Practical limitations to the application

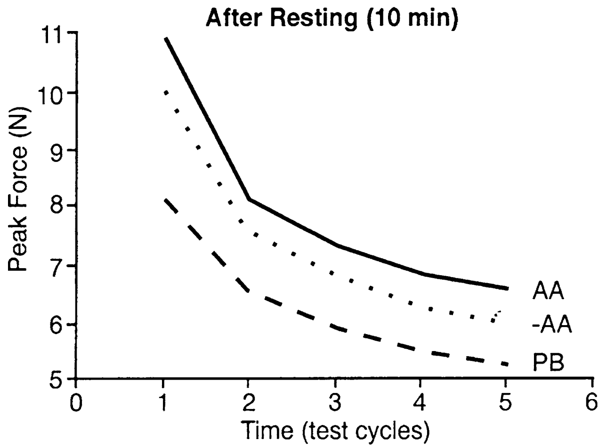

Fig. 2.8 Comparison of effects of ascorbic acid and potassium bromate on dough resistance to deformation (AA = with ascorbic acid, —AA = without oxidant, PB = with potassium bromate)

of partial vacuum are the reduction of the amount of oxygen available for ascorbic acid conversion and the need for some air to be occluded to provide gas bubble nuclei (Baker and Mize 1941). The degree to which mixer headspace can be lowered when mixing doughs in CBP-compatible mixers varies according to the machinery design and operational practices but commonly lies between 0.3 and 0.5 bar.[2]

The rheology of doughs from CBP-compatible mixers is also affected by changes in improver formulation, especially those related to dough oxidation. Cauvain et al. (1992) have shown that the resistance to deformation of CBP doughs was greater when ascorbic acid was compared with potassium bromate as the sole oxidizing agent (Fig. 2.8). This effect is most likely to be accounted for by the difference in the rate of action between these two oxidizing materials, with that for ascorbic acid taking place in the mixer and for potassium bromate mainly in the later stages of proof and thereafter. Other increases in resistance to deformation are observed when the oxidation from ascorbic acid is increased by modifying the mixer headspace atmosphere. Once again, a reduction in resistance (or perhaps more correctly a restoration to standard) may be affected by changing the levels of added water, although in commercial practice the addition of other ingredients in improvers, e.g. enzyme-active materials, may act to reduce dough resistance and increase dough stickiness (Fig. 2.8).

[2] Confusion over pressure units can exist because of the way in which they are expressed. In part this arises because gauges fitted to mixers often express atmospheric pressure as being 0. A partial vacuum may be given as 0.5 bar vacuum and positive pressure may be given as 0.5 bar pressure. In this discussion atmospheric pressure is taken as being equal to 1 bar (or full vacuum = 0). Thus, a figure of 0.5 bar is 0.5 below atmospheric pressure, 0.3 bar is 0.7 bar below atmospheric, and 1.5 bar is 0.5 bar above atmospheric pressure.

Other Breadmaking Processes

Radical Bread Process

Interest in the manufacture of bread using less energy intensive processes while retaining the main elements of bread quality associated with Mechanical Dough Development led to the launching of the Radical Bread Process by Campden BRI, UK (Tucker 2011). The process is essentially a 'no-time' dough process in that the dough leaves the mixer and is processed without delay. However, unlike other doughmaking processes the bulk dough is not divided into unit pieces immediately after leaving the mixer, rather the bulk dough is transferred from the mixer and immediately processed by sheeting with unit pieces being cut and assembled from the sheeted and laminated dough some time after leaving the mixer.

The essential features of the Radical Bread Process were described by Miller and Tucker (2012) as:

- Combining the ingredients into an underdeveloped dough.
- Subjecting the dough to deformation shear by using lamination.
- Cutting the developed dough into pieces.
- Positioning the dough pieces in a pan so the laminations lie in one direction.
- Proving, baking and cooling as for pan bread.

The concept of an 'under-developed' dough was described mixing the dough long enough to achieve a homogeneous distribution of the ingredients and the complete hydration of the flour. As a result of limiting the time that the dough ingredients spend in the mixer there would be significantly less temperature rise (and lower energy consumption). The lower level of energy transferred to the dough by other means was the basis of the method. It was considered that many mixers could be used for preparing the dough though the development work was reported as being carried out with a high intensity Tweedy mixer. Dough development is considered to be achieved during the sheeting and laminating processes which follow mixing. In this respect the preparation of the dough is similar to that that referred to above for the preparation of competition breads based on a low intensity mixed dough, a resting period (bulk fermentation) and the modification of the dough with a pastry brake.

The creation of dough layers through the lamination process and cutting so that the alignment of the layers occurs in one direction are at the heart of the process. In one respect the elongation and re-alignment of gas bubbles in the dough piece are reminiscent of four piece moulding. Though in the case of the Radical Bread Process the impact may be greater because of delivery of more cells as disk-shaped ellipsoids. The end result is to create sandwich breads with more cells, less cell volume in the slice, and a brighter and softer crumb (Miller and Tucker 2012).

Sour Dough Processes

The manufacture of sour dough bread has a long history and is based on the spontaneous fermentation of flour through the symbiotic relationship between bacteria and wild yeasts. Variations in the microflora, fermentation conditions, types and ratios of raw materials are responsible for differences in the functionality of the sour and subsequent flavour in the bread. Sour dough technology is commonly based on wheat or rye flours, or a mixture of both. Such breads have distinctive acid flavours largely arising for the ratio of acetic to lactic acid flavour notes and the manufactured breads are denser with a less aerated structure than many other wheat breads.

The concepts of modern sour dough technology is still based on the preparation of a 'starter' or 'mother' dough to exploit the principles of spontaneous fermentation. Since the fermentation process cannot proceed without the presence of cereal starch as a food source for the microbial activity, it would eventually come to an end and so it is necessary to 'top-up' the food source with more flour (source of starch) in order to sustain the process. Each mother dough has its own unique starting culture of microorganisms which delivers its own special character and flavour profile in the finished bread. Bakers may choose to utilise specialist prepared sours which have been dried for supply to bakers who do not wish to manufacture and maintain their own starter.

The most common starter comprises only flour and water, replenished on a daily basis with new flour as required. The ratio of flour varies according to the preferences of the baker. The two most common forms of sour are those based on wheat and those based on rye. While their preparation is based on similar principles, the technical rationale behind their use is quite different. Some of the common sours may be described as follows:

- *Levain* based on spontaneous fermentation by 'wild yeasts' including *Saccharomyces* (S.) and *Candida* (*C.*) families, and the presence of *Lactobacilli* (*L.*). A variation is the *levain de pate* or pre-leavened dough where the addition of bakers' yeast plays a role in the preparation of a 'mixed' sponge. The daily preparation of an acidic sponge is still required.
- The San Francisco sour dough associated with *L. sanfranciscensis* because it was in San Francisco, USA, that the microorganism concerned was first isolated and identified from dough. Usually a greater proportion of the total flour used in its preparation.
- The Poolish (Polish-style sponge) is a relatively liquid system comprising equal parts of flour and water. As its name suggests it was developed in Poland, probably sometime in the middle of the nineteenth century, and later adopted in Vienna and subsequently France (Calvel et al. 2001).
- The Biga which is a stiff commonly used in Italy with the addition of baker's yeast. Typically it is fermented overnight (12–16 h).
- Rye bread sours (Schunemann and Treu 2001).

In the sour dough culture the symbiotic relationship between bacteria and yeast is important in sustaining fermentation. The bacteria ferment the more complex (larger molecular weight sugars) that the yeasts cannot use and fermentation is sustained because the yeast can metabolise the by-products of the bacterial fermentation (Cauvain in press). Each microorganism present in the microflora mix has a set of conditions in which it works best, with the major impact coming from the pH of the matrix and the temperature at which the sour is held. While the basic principle of the sour relies on symbiosis between bacteria and yeasts, there is also a competitive element to the relationship in that if storage conditions favour one organism more than another, the favoured organism may multiply to limit the potential of others.

After preparation and mixing of the bulk dough, it will be divided into unit pieces, shaped according to local preferences and then proved and baked. As noted above the final products tend to be denser than many other breads, often with a chewy texture. The mould-free shelf-life of sour dough breads tends to be longer than that of many wheaten bread products because of the lower pH and lower overall moisture content (water activity) the final product.

Breadmaking Processes, Bread Variety and Bread Quality

Each of the breadmaking processes discussed above has particular advantages and disadvantages and almost all types of bread and fermented goods can be made with each of them. There are, however, some combinations of breadmaking process and product type which are more successful than others, and because of this successful ‘partnership’ there has been a narrowing of views, a closing of minds and a limiting of the potential for all breadmaking processes. It was never the intention of this chapter to review in detail the advantages and disadvantages of each of the breadmaking processes though some references to such matters have been made where deemed appropriate. It will, however, be useful to conclude by considering how product requirements might influence the choice of breadmaking process.

Reference has already been made to the link in many minds between the fermentation process and bread flavour. All current breadmaking processes involve at least one fermentation period, namely the one bakers call proof. Whether sufficient bread flavours are achieved within that one relatively short process will be endlessly debated because, as commented on earlier, bread flavour is a personal issue. For those who require more flavour in their bread crumb, then the introduction of other fermentation stages is possible. With the introduction of a fermentation stage other than that required for proof come other factors which contribute to bread quality, the main one being an element of dough development, such as that seen in bulk development processes. Having chosen to make a ‘flavourful’ product then the baker must reconcile that requirement with a compatible breadmaking process. The choice of flavourful bread and no-time doughmaking process is not as incompatible as many would have us believe. There is absolutely no reason why we should not combine the benefits of better process control from no-time doughs with flavour, and several examples of using sponges to generate flavour before adding to no-time doughs have been discussed above.

Possibly more difficult to reconcile for the different breadmaking processes is the generation of the required cell structure for a particular product. Many bread products have distinctive crumb cell structures without which the product will simply not be authentic. The major difficulty lies not in making an open cell structure with a given breadmaking process since, as we have seen with the CBP this may simply be a case of using a longer first resting period (intermediate proof), but rather in the creation of the fine cell structures that are required for many breads. The strong link between the formation of an open cell structure and a crispy crust must be recognized, but again there is no reason why this should limit the breadmaking process chosen to achieve these given aims.

No-time doughmaking methods offer the best opportunity of achieving the finer cell structures since little expansion of the gas cells normally occurs until after the dough has been moulded. Provided we have achieved 'optimum' dough development and do not treat the dough harshly during processing, we should retain all the necessary dough qualities to guarantee a fine crumb cell structure. Of the no-time doughmaking methods which have been discussed, the contribution of energy in mechanical dough development appears to offer the best opportunity for achieving this result.

In conclusion, we can see that it has been possible to study the underlying technology of breadmaking processes by considering the many variations which are used under four broad headings. Each breadmaking process offers unique advantages and disadvantages but there are few bread products that cannot be made with any one, once we as bakers have balanced our product requirements with our available raw materials and our process control needs.

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