Technology of Breadmaking

Second Edition

Stanley P. Cauvain and Linda S. Young

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Springer

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Preface to the Second Edition

The manufacture of any processed food is constantly evolving and breadmaking is no exception. Even though bread has been made for thousands of years and its traditional forms remain as strong today as they did in past times, new ideas and new technologies are being developed and adapted to underpin modern production.

While new technologies will undoubtedly continue to drive developments in breadmaking, its traditional basis should not be neglected. Increasing diversity of products in part driven by consumer demand will contribute heavily to the future of breadmaking. More frequent travel and increased global communications expose many more people to the diversity of bread products. What is a traditional product in one part of the world is the novel product in another.

Since writing the the first edition of the *Technology of Breadmaking*, the knowledge base on which breadmaking is founded has undergone considerable enlargement and fuelled many of the more recent product and process developments. This second edition sets out not only to update the first edition but also seeks to identify and discuss the new knowledge that has become available since the mid-1990s or so.

We wish to thank those original authors who willingly gave their time to revise their original contributions.

Stanley P. Cauvain and Linda S. Young

Preface to the First Edition

Not another book on breadmaking! A forgivable reaction given the length of time over which bread has been made and the number of texts which have been written about the subject.

To study breadmaking is to realize that, like many other food processes, it is constantly changing as processing methodologies become increasingly more sophisticated, yet at the same time we realize that we are dealing with a foodstuff, the forms of which are very traditional. We can, for example, look at ancient illustrations of breads in manuscripts and paintings and recognize products which we still make today. This contrast of ancient and modern embodied in a single processed foodstuff is part of what makes bread such a unique subject for study. We cannot, for example, say the same for a can of baked beans!

Another aspect of the uniqueness of breadmaking lies in the requirement for a thorough understanding of the link between raw materials and processing methods in order to make an edible product. This is mainly true because of the special properties of wheat proteins, aspects of which are explored in most of the chapters of this book. Wheat is a product of the natural environment, and while breeding and farming practices can modify aspects of wheat quality, we millers and bakers still have to respond to the strong influences of the environment.

The quality of the baker's main raw material, wheat flour, varies and so special knowledge is needed to ensure the right product qualities are formed in the bread for the consumer. Since some of the most significant changes in wheat quality are related to the environment in which it is grown, a most important tool for bakers is knowledge, without it they cannot adjust recipes or processing methods to ensure consistent product quality.

It is because breadmaking requires constant reaction to 'natural' changes and it has been the subject of scientific and technological study that there is room for another book on the subject. New ideas are being presented to bakers from wheat breeders, millers and ingredient and equipment suppliers, which are coupled with consumer and legislative pressures. These have to be integrated with 'natural' changes.

It is the purpose of this book to provide a useful tool to help bakers, scientists and technologists to cope with those changes. We hope that when you read through the contributions you will find something to make your particular job easier, or even something to enjoy.

As you read through the various chapters there will be occasions when you say to yourself 'I've read about that before'. When you get different authors to write about breadmaking, they have to consider the same common themes but they will approach them from their own special angles. The most common theme of course is the conversion of wheat to flour to bread. Each individual involved in that conversion process has a contribution to make, but in order for that contribution to be successful they must understand what part they play, and because of this they have different needs in their understanding. These different needs will be evident as they discuss common issues such as gluten development, so

- the cereal scientist seeks to understand the molecular reactions;
- the bakery technologist seeks to apply the understanding and solve bakers' problems;
- the flour miller seeks to ensure a consistent product by understanding the links between wheat, flour and bread quality;
- the ingredient suppliers seek to understand the contribution of their ingredients to bread quality;
- the equipment manufacturers seek to understand how dough behaviour interacts with their equipment; and
- bakers seek to make bread for their customers.

Editing a book of this type, just like breadmaking itself, is a team effort, and so we would like to thank the members of our team:

- The authors of the individual chapters who having agreed to write a contribution discovered like so many before that it is not as easy as it looks when you read a book written by someone else. We thank all of you for patience and perseverance.
- The publishers without whom this book would not have seen the light of day.
- Our many supporters, both moral and material.
- Our scientific mentors.

Why thirteen chapters? That is easy to answer – thirteen is the traditional 'bakers dozen'.

Stanley P. Cauvain and Linda S. Young

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Bread – the Product

Stanley P. Cauvain

1.1. Introduction

Bread in its many forms is one of the most staple foods consumed by humanity. Traditionally bread is based on flour derived from the cereal wheat. Many other types of cereals, pulses and even legumes can be milled to give a 'flour' but the ability of the proteins present in wheat to transform a gruel of flour and water into a glutinous mass which becomes bread is currently limited to wheat and a few other commonly used cereal seeds. Genetic manipulation may yet combine the special protein characters of wheat with other more conveniently grown and processable seeds, for example to deliver no crease or a more rounded shape, but today we are still dealing with a cereal crop largely unchanged, in the genetic sense, from the time that humanity discovered its ability to make a special food many thousands of years ago.

Many consider bread to be one of the oldest, if not the oldest 'processed', food. We are unlikely ever to identify the moment when bread was 'discovered' though it is likely that the place of discovery was in the Middle East where the origins of cereal farming also lie in antiquity (Zohary, 1969). In its earliest forms, bread would have been very different from how we see it in industrialized countries today, and it would probably be closest in character to the modern flat breads of the Middle East. We will probably never know whether the gathering and cooking of wild grass seeds provided the spur to arable farming or whether the ability to grow and harvest the forerunners of modern wheats provided the impetus for breadmaking. Whichever way round the two events occurred, there is no doubt that one depends on the other and this simple relationship is the foundation of all modern breadmaking.

The move to improve the digestibility of the wild grass seed forerunners of early wheat types, by cooking or baking, represents a major step in the evolution of human food production. To make this step requires an appreciation, but not necessarily a scientific understanding, of the unique properties of the proteins in the grass seeds we call wheat, namely their ability to form a cohesive mass of dough once the grains have been crushed (milled) and the resultant product wetted (hydrated) and subjected to the energy of mixing, even by hand. This

cohesive mass is the one we bakers call 'gluten', and once formed it has the ability to trap gases during resting (fermentation and proof) and baking and this allows the mass to expand to become a softer, lighter and even more palatable food after the final heat processing.

Another important event in the production of bread was the discovery that, if left long enough, the dough mass would increase in volume without being subjected to the high temperatures of cooking or baking. There is no doubt that the changes in the rheological character of the dough – the way in which it behaved on handling – would also have been keenly observed by those in charge of food production. The combined effect of these changes is for the subsequent baked mass to be further increased in volume and give a product with an even softer, more digestible character and different (improved?) flavour. Gradually the appreciation of the actions of wild yeasts and portions of old dough (e.g. starter doughs) were to lead to the transfer of fermentation technology from the brewing industry and eventually to the production of specialized bakers' yeasts.

Bread is a staple foodstuff and today there are few countries in the world where bread and fermented products are not made and eaten. Bread products have evolved to take many forms, each based on quite different and very distinctive characteristics. Over the centuries, craft bakers around the world have developed our traditional bread varieties using their accumulated knowledge on how to make the best use of their available raw materials to achieve the desired bread quality. Commonly this has been by adapting and changing pre-existing processing techniques and on occasions developing entirely new ones. Today, scientific study and technical development provide faster and more cost-effective ways of making bread, but even so bakers still have to use their collective knowledge, experience and craft skills to integrate the available raw materials and processing methods to satisfy their customer demands for fresh, wholesome and flavoursome fermented products. While our basic raw material, wheat, is generally much improved in quality and more consistent in performance, it is still a 'natural' material and as such is continually subjected to the influence of environmental factors during growth, at harvesting and during storage. All of these factors, and others, contribute both individually and collectively to variability in wheat during milling and flour performance during breadmaking.

In some countries the nature of breadmaking has retained its traditional form while in others it has changed dramatically. The flat breads of the Middle East and the steamed breads of China are examples of traditional bread forms which still remain an essential part of the culture of the countries where they are still produced in large quantities. On the other hand, in North America the arrival of wheats along with settlers and farmers from Western Europe was to lead eventually to production of new wheat varieties and the rapid industrialization of breadmaking in a country where the maize-based products of the native Americans had previously been the main cereal-based foods.

Today consumers are becoming increasingly cosmopolitan in their taste for bread as the influences of international travel and cultural exchange lead to a wider appreciation of the infinite variety of bread. In the UK, for instance,

Italian ciabatta, Indian chapattis and French baguette are all eaten along with UK-style sliced bread, and so for those of us who enjoy eating bread there is truly ‘something for everyone’.

1.2. Quality Characteristics of Bread

The product which we call bread today represents the progressive technical development and improvement of fermented wheat-based products over many thousands of years. In common with most, if not all products of modern life, the evolution of breadmaking processes has progressed further since the mid-1940s than in all of the preceding centuries and yet, because it is ‘that most ancient of foods’, it still evokes the most passionate of discussions about quality, taste and value for money. You have only to spend an hour or two in a room with bakers to appreciate just how emotive a subject breadmaking is, a strange mixture of craft, science, technology and to many ‘love’.

The proliferation of bread varieties, a few of which are illustrated in Figure 1.1, derives from the unique properties of wheat proteins to form gluten and from the bakers’ ingenuity in manipulating the gluten structures formed within the dough. The rubbery mass of gluten with its ability to deform, stretch, recover shape and trap gases is very important in the production of bread and all fermented products. Of all the cereals, wheat is almost unique in this respect. Some other cereal flours, such as those derived from rye and barley, can form gluten but

FIGURE 1.1. Bread varieties: rear left — mixed grain; rear right — sandwich; middle — baguette; front — ciabatta.

to a lesser extent than normally seen with wheat flours. It is possible to mimic some of the character of wheat-breads with products made from other cereals but if similar volume, crumb characteristics and flavour to wheat-based breads are required then any natural proteins present must be supplemented with other sources of gas-stabilizing ingredients, whether they are protein, carbohydrate or lipid based.

With such a long history of production and such diversity of form, bread-making is almost always an emotive subject. Whenever the subject of quality is raised amongst bakers and consumers, we can guarantee that there will be a diversity of opinion, with different bakers extolling the virtue of different breads, different processes, different doughmaking formulae and different ingredients. In these circumstances it is meaningless to describe bread as being 'good' or 'bad' (unless there is a genuine quality problem which renders it inedible), since the phrase 'good bread' will have a different meaning to each of us depending on our cultural background, our individual experiences and our personal likes and dislikes. For example, there are many supporters of the dense wholemeal (wholewheat) bread that one may typically make at home and they will find the large-volume, soft wholemeal of the plant bakery unacceptable, but the latter form will find greater acceptability in sandwich making for retail sale. It is interesting to note that while the quality characteristics of these two types of wholemeal bread may be very different, the nutritional and health benefits, if we ignore digestibility, remain largely the same.

We use the term 'bread' to describe a range of products of different shapes, sizes, textures, crusts, colours, softness, eating qualities and flavours. The characters of the products are diverse, and because of this the terms 'good' or 'bad' quality have no meaning, except to the individual making the assessment. A baguette is not a baguette without a crisp crust while the same crust formation would be unacceptable on North American pan bread. The fine cell structure of sandwich bread in the UK has no relevance to the flat breads of the Middle East. Clearly the 'ideal' loaf depends on who you are and where you are. Today we find bread made and eaten in parts of the world where wheat is not an indigenous crop and because of this some of the essential characters of bread have become universal, the form may be different but we all largely seek many of the same attributes from all of our fermented products.

Despite there being as many opinions on what makes 'good' bread as there are bakers and consumers, it is true to say that certain quality characteristics are required for different varieties to be acceptable to the widest cross section of consumers. For example, baguettes are characterized by a hard and crisp crust and without it we would reject the product, often describing a baguette with a soft crust as 'stale'. On the other hand, sliced pan breads in the USA, the UK and elsewhere are characterized by a thin but soft crust, and if the crust were thick and hard it would often be rejected by consumers, ironically also being described as 'stale'.

Loss of product freshness is as much about what we expect a product character to be as it is about its age since original manufacture. Whatever the criteria

we use to judge bread staleness, it becomes clear that the single most common requirement of a fermented product is that it should ideally retain all of the attributes which it had when it left the oven; above all else we expect our bread to be 'fresh'. When we collect our bread from the baker and it is still warm to the touch we have no doubt as to its freshness but when we purchase it cold from the store shelf we need convincing of its freshness. The pursuit of fermented products which retain their 'oven-fresh' character for an extended period of time after they have left the oven has been one of the great challenges facing bakers, technologists and scientists for many years, and many different strategies have been evolved to meet this challenge. Whether they have been successful can really only be judged by consumers.

To be able to make our particular bread type, we must have an understanding of the complex interactions between our raw materials and the methods we will use in the conversion processes from ingredients to baked product. Our raw materials will change and our processes are time- and temperature-sensitive. Given the intricate nature of the process, it is a wonder that we manage to make bread at all. We do so because of accumulated knowledge – craft – augmented these days by scientific and technological understanding.

1.3. The Character of Bread

What are the essential characters of breads? How do we distinguish them from cakes, pastries and biscuits? We have already considered that 'bread' requires wheat flour (mostly) and water to form gluten to trap the gas generated by the added yeast. We usually see at least one other ingredient used, namely salt, which is added to give more flavour to the baked product. Not that flour and water, when mixed and baked, with or without yeast, has no flavour since the very action of baking develops flavour compounds in the crust, and natural bacterial and wild yeast actions can also develop flavours within the bread crumb.

To some extent we can argue that a definition of the character of bread can be based on the ingredients used. To many, an essential difference between bread and other baked products is that cakes, some biscuits and some pastries contain sugar to confer sweetness (and other less obvious properties), but in the USA bread commonly contains added sugar, as do the sweet breads of India. In addition, where would we place fermented buns and rolls? The other ingredient commonly present in relatively high proportions in cakes, pastries and biscuits is fat. Most breads contain much lower proportions of fat than cakes, but where then do we fit fermented products such as croissant?

The fact is that we can never form a concise definition of bread since it is characterized by all of the ingredients we use to make it, and more besides. An essential component of bread is the formation of gluten, a process which does not occur in cakes to any significant degree and indeed is actively discouraged by the addition of sugar and, to a lesser extent, fat and the use of high level of water addition. Most biscuits and pastries also have limited gluten formation by

comparison with most bread products. In laminated products, however, gluten formation is encouraged and bakers have evolved a specialized layering technique to allow the incorporation of fat for the modification of texture and eating quality but without much disruption of the gluten formation, and so we can say that in the case of croissant and Danish pastries, the addition of yeast places the products in the fermented goods category alongside bread.

In seeking a definition of bread we should not overlook the contribution of the water. Its addition in the 'right' quantity is essential for the formation of gluten and for modifying the rheology of the dough. The level of moisture remaining in the baked product is also a major contributor to the characters of breads. Too much or too little added water during mixing means that we cannot form the 'right' gluten qualities to trap the gases from yeast fermentation. Too little remaining in the baked product will result in the eating character being closer to that of pastries and biscuits.

The character of bread and other fermented products then depends very heavily on the formation of a gluten network in the dough, not just for trapping gas from yeast fermentation but also to make a direct contribution to the formation of a cellular crumb structure which after baking confers texture and eating qualities quite different from other baked products. Look closely at the crumb structures of most baked breads and you will see that the common linking theme is that they are formed of holes of differing shapes, sizes and distributions, each hole being embraced by a network of connected strands, coagulated gluten, in which starch granules and bran particles are firmly embedded. When this crumb is subjected to pressure with the fingers it deforms and when the force is removed, it springs back to assume its original shape, at least when the product is fresh. This combination of a cellular crumb with the ability to recover after being compressed largely distinguishes breads from other baked products and these are the very characteristics that bakers seek to achieve in most bread products.

1.4. Bread Flavour

Nothing will provoke more debate in discussions on bread characteristics than that related to the flavour of fermented products. The judgement of what constitutes the 'right' flavour is another highly personal and emotionally charged issue. Sometimes bread products are eaten alone, but more often they will be eaten as an accompaniment to other foods in a meal or as part of a composite product, so that bread flavours tend to be more subtle than we would encounter in many other foods.

The development of flavour in fermented products comes from a number of different sources and includes contributions from the ingredients and the processing methods which are used. Many of the ingredients which are used in the production of fermented products make a significant contribution to the flavour of the product. Flour tends to have a fairly bland flavour with most of its contribution coming from the oils of the germ (embryo) and bran particles

present. Since this is the case, we can reasonably expect that wholemeal, wholewheat and bran- and germ-enriched white flours will yield bread with more flavour than white flours.

Breadmaking around the world has evolved many dough formulations which use ingredients to confer special flavours which have now become an essential part of that product character. The addition of salt (sodium chloride) to bread is the most obvious of those flavour modifiers, imparting both its own characteristic 'salty' taste and working in the mouth to increase our perception of other flavours which may be present. Since salt levels vary in many products so will our perception of flavour between products. Other common additions include fat, sugar, milk and malt products, each contributing its own special flavour. The level of yeast used in the recipe also makes its own unique contribution to bread flavour.

During the natural fermentation processes which occur in breadmaking, new flavour products are generated within the dough (Wirtz, 2003). Both the intensity of those flavours and the particular flavour 'notes' which are developed change with increasing fermentation time. The most commonly observed flavour changes are those associated with the development of acid flavours from microbial activity in the dough, which are readily detected in the flavour of the bread crumb. Not all of this flavour activity will come from the addition of bakers' yeast; some will come from wild yeasts and bacteria, especially lactic acid bacteria, which are present naturally in the flour. Usually several hours of fermentation are required before there are significant changes to the flavour profile of the bread crumb. Where the breadmaking process being used has no provision for lengthy fermentation times, it is often the practice to develop flavour in a 'pre-ferment', 'brew' or 'sponge' which is later mixed with the remaining ingredients to form the dough for final processing.

By far the most important contribution to bread flavour comes from the process of baking. During this heat-setting stage many of the flavour compounds present undergo major changes; some old ones are lost and many new ones are formed. We most readily see this phenomenon in the formation of a dark, mostly brown crust on the outer surfaces of the dough. These changes are associated with the complex processes commonly referred to as 'Maillard browning' and many of the compounds are highly flavoured. These compounds are very important to our perception of flavour in many baked foods, and views have been expressed that as much as 80% of bread flavour is derived from the product crust. In an interesting parallel in the bakery world, we have seen the introduction of the so-called 'high-bake' water biscuit, confirmation of the contribution that browning of the crust makes to flavour and quality.

The perception of flavour in bread is, then, no simple matter. It will, for example, be strongly influenced by the ratio of crust to crumb. The development of Maillard browning products during crust formation may help us understand why products as different as UK sandwich bread and French baguette have different flavour profiles. In the case of baguette, the proportion of crust to crumb is much higher, so that we will have a larger quantity of compounds

which contribute to product flavour. The lower proportion of flavour compounds in UK sandwich bread may be seen by some as being to its detriment, but then the character of the bread is aimed at a completely different end use to that of the baguette.

1.5. Bread Types

The development of particular types of bread has taken different directions in different parts of the world. As a consequence, not all of the terms used to describe breads and their quality attributes have the same meaning in all parts of the bakery world and this sometimes leads to misunderstandings between individuals regarding bread quality. The most obvious of examples are references to French breads which in the UK tend to be used to refer to baguette styles while in the USA may refer to pan breads with lean (i.e. low-fat) formulae, such as might be used in the production of French toast. In France the concept of 'French' bread as viewed in the UK would not be widely understood. Similarly, the term 'toast breads' will have different meanings in France, the USA and the UK. We must recognize that the use of bread-quality descriptors and product terminology will be strongly linked with local consumer preferences and traditions, even though in general the terms used to describe the quality attributes of fermented products can mostly be related to the categories of external and internal characters, eating quality and flavour as discussed below.

The characterization of a particular bread type will always include a description of its physical appearance, usually starting with its external form. Thus baguettes are likely to be described by their length and diameter, other bread forms by their pan shape, Middle Eastern and traditional Indian breads as 'flat' (Figure 1.2) and so on. Even markings on the surface may require definition, in the way that the number and direction of cuts on the dough surface may become an integral part of the traditional product character. A comment on the product crust colour may be included. Almost certainly a description of the interior appearance follows with references to the sizes, number and distribution of holes in the crumb and the colour of that crumb. Comments on crust hardness and the eating qualities of the crumb will almost certainly be made and there is likely to be some reference to the flavours present. To help with the characterization there may be references by the describer to other bread types, such as 'flatter than…' or 'with more holes than…'.

How often do we take a few moments to ask ourselves fundamental questions about the character of bread products such as 'Why is a baguette the length and shape it is'? The very attributes which characterize baguette or any other particular type of bread were identified many years ago and have become enshrined in our perception of the required product quality for a given loaf. For example, whoever heard of a baguette baked in a round pan? There is no reason why we should not make pan breads with crisp crusts and open-cell structures like those we normally see in baguette, but even if we do it is most

FIGURE 1.2. Naan bread from India.

unlikely that we would try to call it a baguette because most of our customers would not recognize it as such; essentially they would not view the product as 'authentic'. In discussing the technology of breadmaking we must recognize that most bread types are the product of long-forgotten traditions rather than the systematic development to give a specific product character.

Reference has already been made to the techniques of cutting the dough surface before baking. Such markings have become part of the traditional character of many breads, like baguette, coburgs and cottage loaves (in the UK). As well as providing a distinctive appearance they also play a significant role in forming many aspects of product character. In some products the cutting of the surface exposes a greater surface area to the heat of the prover and the oven and thereby improves expansion in both of these stages. In the oven the product may expand in a more controlled manner if the surface has been cut, and this may improve the overall product shape. This effect is readily observed in the inclination for the upper part of cottage loaves to become displaced during baking if the lower part has not been cut correctly before entering the oven.

The depth and direction of cutting contributes to the expansion and ultimate volume of a product, an effect best illustrated by once again considering the baguette. The 'traditional' French baguette is given a fixed number of shallow cuts, largely following the length of the dough piece (Figure 1.3), while in other parts of the world more numerous cuts may be made across the breadth of the dough piece. The first technique encourages the retention of much of the gas in the dough and confers greater expansion during baking, while the latter technique

FIGURE 1.3. Surface cuts on baguette.

is more readily inclined to release gas during baking and give a smaller volume in the final product, but of course calls for less skill on the part of the baker.

Such comments are not intended to denigrate or glorify any particular bread product, rather to show the traditional basis of the many bread types we encounter. There are a few relatively modern bread developments, but most of our bread types have a long period of development. However diverse our bread types are, they share a number of common elements largely based on the formation of gluten as discussed above and in more detail in later chapters. There are two main elements of bread: the crust and the crumb. The physical form of both crust and crumb and the ratio of one to the other are the very essence of what distinguishes one type of bread from another. The size and the shape of the loaf, together with the ingredients used, contribute to the overall quality but arguably such contributions are of lesser importance to bread character than those made by the nature and proportions of the crumb and the crust.

While we as scientists, technologists, bakers and consumers can earnestly debate the relative merits of crisp and soft bread crusts, we should not lose sight of the contribution that crumb structure makes towards these aspects of bread quality. The crisp baguette crust forms in part because of the open-cell structure created in the dough during processing and baking, while a fine, uniform cell structure is essential for the pan breads and must be created at the beginning of the process, principally in the mixer. Achieving the 'right' bread quality calls for the creation and control of gas bubbles in the doughmaking, moulding, proving and baking processes. These bubble structures eventually become the bread cell structure when the dough mass is heat set during baking.

The many different bread types which have been evolved with the passage of time all require their own individual bubble structure, processing techniques, processing equipment and process control mechanisms. It is an understanding of each of these factors against a background of an ever-changing raw material quality which allows bakers to maintain traditional bread qualities and to develop new ones in a changing market place. The challenges are many but the manufacture of 'good' bread still remains a pleasure for those of us involved in its production.

1.6. Assessing Bread Quality

The process by which bread quality is determined still relies to a significant extent on subjective assessments by experts because of the difficulties associated with objective measurements of some highly 'personal' characters in breads. The most obvious examples of the assessment problems we face are those characters related to flavour and eating quality because of the diverse preferences of individual consumers. Nevertheless if we as bakers, technologists and scientists are to be in a position to assess the effects of new ingredients and processing methods, to match more closely bread quality with consumer requirements or to reduce product variability and limit quality defects, then we must have some basis on which to make our quality judgements. To state simply that a particular change of formulation has 'improved' bread quality is inadequate for others to judge the success of our efforts or for us to make longer-term assessments. Therefore we need to have objective criteria and in cases where this is not possible we need to standardize as much as possible the methods we use for our subjective assessments.

Various scoring techniques are usually employed to try and standardize subjective assessment (e.g. Kulp, 1991). The attribution of particular numbers will be based on individual requirements. Photographs or diagrams with attribute scores are often used as the basis for comparison between test and standard by the observer. In this way uniformity of scoring is improved.

The techniques for assessing bread quality usually fit into three broad categories: external, internal and texture/eating quality, which includes flavour.

1.6.1. External Character

Among the characters we most often assess under this heading are product dimensions, volume, appearance, colour and crust formation.

The critical dimensions for most breads are their length and height, with breadth being of lesser importance. A large number of bread types are characterized by their length, for example baguette which should be 70 mm long in France (Collins, 1978). Devices for measuring product dimensions off-line can be simple and include graduated rulers and tapes. It is possible to measure product height and shape on-line using image analysis techniques. Measurement