What makes bread?

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Bread making has been with us for 10,000 years or more and is commonly considered to be one of the first, if not the first, processed foods. Throughout the centuries the collective craft skills of many bakers have developed the many different types of bread that we see around the world today. More recently, certainly from the 1950's in the major industrial countries, we have seen the progressive change from craft to major plant bakeries, a trend which continues today, even in those countries with a strong traditional craft bread base.

It is inevitable that scientists should turn their attention to the somewhat magical transition of flour and water into the light and palatable food we call bread. Traditionally salt and leavening, ultimately in the form of bakers' yeast, have been added to flour and water to 'improve' the end result. For a long time bakers and scientists have been able to identify the critical role that flour proteins play in controlling bread quality and we are all familiar with the concept of gluten. That wonderful rubbery substance that forms in bread dough which allows it to rise in fermentation and during baking.

For many years cereal scientists, including myself, have toiled to explain what makes bread and written many articles and books on the subject and we now have many sophisticated plants dedicated to producing thousands of loaves an hour. Yet when you go into bakeries around the world as I do to sort out quality and consistency problems it is amazing to see how difficult it is to identify what controls bread quality and how we can adjust it. It remains a matter of skill, trial and error, and above all – craft. Today I want to take a look at some of the latest research results from around the world and see if we are any closer to answering the key questions – What makes bread?

It is clearly understood that two key processes underpin modern bread production; the production of carbon dioxide gas by bakers' and its retention in the dough by the gluten structure developed in the dough when we mix flour and water together.

What is also clearly understood is that some modification to the gluten structure that we have at the end of mixing is required in order to improve the quality of the baked product. In particular changes to the dough character occur which improve the ability of the gluten to retain more of the carbon dioxide gas produced by the yeast.

Collectively we refer to these as changes in dough rheology and we see that with extended fermentation time the gluten become more extensible and just like an elastic band we can stretch the protein network further before it snaps and releases the gas from within the dough structure.

The critical role that energy plays in forming a gluten structure and extensible gluten network was first recorded in 1926. In the later 1950's research at Chorleywood led to the development of the Chorleywood Bread Process in which the input of energy as a critical component in the production of bread was fully recognised.

It has been known for some time that that flours with different characters require different levels of work input in order to achieve optimum bread quality. In the UK wheats with high protein level or ones with significant elastic properties have long been classed as 'extra strong', or as Bill Collins often referred to them 'extra difficult' in the CBP. Bill's reference was to the fact that higher energy levels were required to fully develop the underlying gluten structures and this was not always possible to achieve during normal mixing cycles.

But why does energy play such an important part in forming a gluten structure with the rheological character that we seek?

If one mechanism has eluded the cereal scientist it is the principles by which gluten is formed during mixing in the dough. In the early stages of mixing the intimate contact between flour proteins and water results in the formation of protein fibrils as the flour particles 'explode' during the hydration process.

Continued mixing leads to the breaking and reforming of protein bonds in the dough. In no-time doughs oxidation of the water-soluble –S-H groups in the proteins removes them from the system and the disulphide bonds, the –S-S- are formed. The theory of disulphide bond formation and factors which contribute to their formation and dough breakdown have underpinned our understanding of dough making for many years.

Yet despite the longevity of the hypothesis many of us have been conscious for some time that this is not the full story.

In the last few years another part of the story has begun to emerge with the realisation that bonds formed between tyrosine linkages in the protein chain could make a significant contribution to gluten formation in dough.

This slide shows a number of different peaks which relate to the formation of tyrosine-type peaks with extended dough mixing. The peaks were not present or were present at very much lower levels in flour and so represent the changes which occur during dough development.

Dr Kathy Tilley of Kansas State University has been foremost in putting forward the hypothesis that the formation of tyrosine peaks are an important component of dough development. Her hypothesis has not won instant acclaim but her data support the practical results that one gets from using potassium bromate as an oxidising agent; namely that there is little increase in di-tyrosine linkages during mixing but a significant change in the early stages of baking.

I am pleased to be able tell this audience that a joint study between CCFRA and KSU confirms the practical understanding for the effect of ascorbic acid; namely that there are changes in tyrosine-type bond formation which are greatest during mixing and least during proving and baking. Thus it is clear that the di-tyrosine hypothesis has direct relevance for European breadmaking processes.

New research based on studies of dough mixing using NIR coming from a team led by Dr. Sam Millar at the RA has confirmed the critical role that energy plays in determining bread quality. The application of NIR to dough mixing studies is based on the potential link between gluten formation and changes in hydrogen bonding of water as mixing proceeds.

With NIR changes in dough character have been observed which show that the optimum NIR mixing time falls roughly between the mixing time required to achieve the finest bread cell structure and the greatest bread volume. As you can see in this graph the finest cell structure occurs at a time before that for greatest bread volume. Thus it appears that some modification or breakdown of the gluten structure is required in order to achieve maximum bread volume in a given mixing environment.

As one might expect, different wheat varieties have different optimum NIR mixing times. In general, the stronger the flour the longer the NIR optimum mixing time. The data I have just shown were derived from studies with a fixed mixing speed so that longer mixing times equate with higher mixing energy inputs. However, the development of the CBP in the 1960's showed that rate of work input was just as important as total work input.

Taking that understanding into the NIR studies has shown an interesting relationship between wheat variety and rate of work input or mixing speed. Comparing a weak and a strong wheat variety we can see mixing speed has had little impact on bread volume or cell structure with the weak flour – Equinox – but bread volume increases and cell structure becomes finer for the Soissons.

The measurement of the torque associated with dough mixing shows how dough rheology varies with rate of work input, in this case achieved by changing mixing speed. At high mixing speeds the doughs are quickly developed and the traces reach a peak value before falling as the dough becomes over-mixed. At lower speeds, however, the situation can be that the dough never becomes developed, that is it never reaches a peak value.

The mixing traces we can see in this slide are associated with the wheat variety Soissons, typically a wheat variety considered to be over-strong for no-time doughmaking processes. Are we then beginning to see why Bill Collins used to refer to extra-strong wheats like Soissons as extra-difficult in the CBP. And how does this fit with the di-tyrsosine hypothesis? As yet we do not know but we hope to have some answers before too long.

Other critical information on what makes bread comes from recent studies by Martin Whitworth and his team at CCFRA who are studying gas bubble structure in dough. Baker and Mize in 1942 provided the platform for much of our understanding when they studied the role of carbon dioxide in bread doughs. For no-time breadmaking processes the change in gas composition during mixing and thereafter reinforces the critical role that nitrogen plays in providing the nucleating sites for the carbon dioxide released by yeast fermentation. The gas bubble population we create in the mixer is essentially the one which will expand in the prover and be set in the oven.

Gas volume fractions and bubble populations in bread doughs vary for many reasons, not least because of wheat variety inlfuences, formulation, mixer design and mixer pressures. We can expect a range of sizes to be present in all doughs. There is a critical size below which bubbles cannot survive, typically in the region of 5-20 microns. We would expect the larger gas bubbles to expand to a greater degree than the ones at the smaller end of our range because the larger ones have a lower internal pressure relative to the smaller ones. This has been the accepted wisdom until recently but new investigations show that the situation is more complex than first thought.

Using X-ray tomography we have been able to study changes in dough structure and with advanced image analysis of bread crumb become able to locate and follow changes in specific dough features. For example, take these two large gas bubbles or holes in the dough. Being large we would expect them to expand during baking and they do as we see them survive in the bread.

Now lets look at these two large gas bubbles in proved dough and their disappearance by the end of baking. The location of the collapsed bubbles can be seen in the crumb and felt as ridges in the crumb surface. Here then is the reverse of the previous slide. Now we talk of some bubbles unzipping during baking while others may zip. Why does this happen? As yet we don't know.

So when we look at a bread slice do we know what caused it to assume the appearance that we see. If we consider that we are expert the answer is yes, but with reservations because we recognise that we still have to much to learn.

Standing her today I cannot answer with much more certainty what makes bread, but I can say that I believe that with the application of the new techniques and knowledge we have briefly discussed today, we are on the threshold of a quantum leap forward in our understanding of how flour, water, yeast, salt and other functional ingredients combine to yield bread.

So far I have avoided answering my own question. In concluding I would life to offer an answer – Question, What makes bread? Answer, people, well at least for the time being. But that as they say is another story for another occasion.