

# THE WHEAT INDUSTRY

Cereals have been of great significance in human history, usually being the first crop to be grown (rather than gathered from the wild) and being the staple food of virtually all people groups until the present day. In New Zealand, the most significant cereal is wheat, which was introduced to New Zealand in the early 1800's. Wheat is used in the production of products as diverse as glue, licorice and ice cream cones, but most commonly it is ground to extract flour which is then used in baking - particularly the baking of bread.

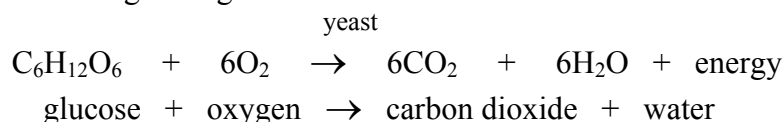
## The structure of flour

Flour is basically composed of starch and gluten, with small amounts of water, fat, vitamins, minerals and enzymes also mixed in. Starch is a carbohydrate (substance composed of carbon, hydrogen and oxygen) composed of glucose molecules linked together. By boiling with acid, or when attacked by enzymes called  $\alpha$ -amylases, starch is converted back to glucose molecules. In bread, this reaction is crucial as the  $\alpha$ -amylases naturally present in flour produce the glucose on which the yeast feeds. Gluten is a protein (substance composed of particular acids known as amino acids), and it forms a lattice in bread that holds it in its shape during baking.

## Bread making

Bread consists of flour, water and yeast with flavouring agents (such as salt and sugar), preservatives (often vinegar), substances that alter the texture (such as milk) and agents that catalyse the chemical reactions occurring (e.g. malt flour). Often a single ingredient performs several of these functions.

The most significant chemical reaction in bread baking is the  $\text{CO}_2$ -producing reaction caused by yeast feeding on sugar:



The energy released helps the yeast to continue growing, and the carbon dioxide is the gas that causes the bread to expand. The kneading of the dough helps to produce bubbles of equal size evenly distributed throughout the dough.

During baking several important chemical changes take place. The enzymes form sugar which initially is used by the yeast for food, and later browns to form the bread crust. More gas is formed, and both the starch and the gluten stiffen to form a solid network base for the bread. During this time the outside of the loaf can rise to over  $200^\circ\text{C}$ .

Bread is an important food in that it is a good source of carbohydrate, fibre, protein, B group vitamins and certain minerals.

## INTRODUCTION

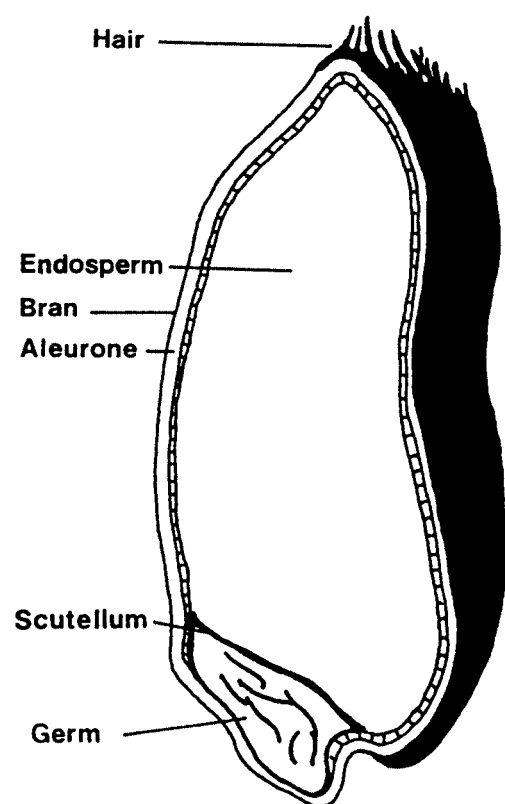
Man created the cereals, and the cereal grains may be said to have created man: indeed, the name of the Roman goddess of agriculture, Ceres, means "Creatress". The growth of settled communities, which led to the possibility of developing arts and sciences, only became possible in Neolithic times because man learnt to domesticate the wild grain-bearing grasses

and cultivate them for his own use. All the world's civilisations have depended on cereals: archaeology has provided evidence of wheat and barley storehouses in Mesopotamia, Egypt, Greece and Italy, and of maize stores in the caves of the Mayas, Aztecs and Incas in the Western Hemisphere.

Cereals provide more than 70 per cent of the calories in the diet in parts of Asia and Africa today. It seems to be a general characteristic of economic development that though cereals continue to provide the staple food their importance in the diet should decline. Nevertheless, throughout the world cereals of some form form the staple food, as well as being fermented into many traditional drinks such as whisky and sake.

The staple cereal in New Zealand today is wheat, although it is only a relatively recent import, having been introduced by the Europeans in the early 1800's. By 1855, 994 hectares of wheat were planted in the North Island and 3 163 in the South Island. Today wheat is New Zealand's major arable crop: a small quantity is exported as animal feed, and it is widely used in the local food industry.

### The structure and composition of wheat



A wheat grain is not round, but has a crease down one side where the grain was attached to the wheat plant by a short stalk (**Figure 1**). At one end of the grain is the "germ" which grows into a new plant when the seed is planted. Around the outside of the grain is a protective coat of bran, whilst in the centre is the white part we call endosperm. The miller's task is to separate a maximum amount of white endosperm to grind into flour, with a minimum amount of germ and bran. 100 kg of whole grain contains about 83 kg of endosperm, but because this clings tightly to the bran, the miller gets only about 78 kg of flour. This is higher than the extraction rate used in some other countries, because we try to scrape into the flour the layer of endosperm just under the bran. This layer, called the aleurone, is particularly rich in some vitamins of the B group. In other countries where lower extraction rates are used their white flours are supplemented with added vitamins and minerals to ensure the good health of the population.

**Figure 1 - A Wheat Grain**

### The uses of wheat

The most common use of wheat is to grind it into flour which is in turn baked into bread. Whilst all the cereals can be ground into a flour or meal, only wheat and rye contain the type of protein that will enable them to be baked into bread. The ancient Egyptians are credited with first making bread by a fermentation process similar to that used today, and bread was used by them in payment of wages. Before this, cereals were probably eaten as porridge or as hard, unleavened cakes, and the earliest stone milling tools date back some 75,000 years.

Flour is produced in many different grades according to its intended use. Pasta flour has a high protein content, while that used for bread baking is slightly lower and household flour has less still. Cake and biscuit baking flours have low protein contents to ensure the product produced is not tough eating. Pastry flour is generally high in protein.

Wheat has many other diverse uses. Whole wheat is used in breakfast cereals, muesli bars and animal feeds (including as an additive to pet foods). Flour is used in baking, to thicken gravies and soups and in the production of ice cream cones, wafers, oxo cubes, pizza bases and pet foods. Wheat extracts are used in the production of glue, licorice and animal feeds. Gluten is added to some flours, and starch is used as a thickener in soups, gravies, spreads and puddings.

## **THE STRUCTURE OF FLOUR**

The first idea to grasp is that flour is composed of fine particles which are not uniform in size and structure. There are two reasons for this variation. The endosperm is made of small oblong boxes called cells, each filled with starch grains embedded in protein, very much like shingle in concrete. The cells are not all the same size, and since during milling the structure tends to split along the cell boundaries, different sized particles are formed. Many of these cells are broken up by the mill into irregular shaped fragments of all sizes, down to individual starch grains and pieces of protein.

Flour contains four kinds of chemical substances which are of importance to baking - starch, gluten, fat and water, the presence of each of which can be easily demonstrated. There are many other substances in flour, such as vitamins and enzymes, but only starch and gluten are discussed here.

### **Starch**

Starch belongs to the group of substances known as carbohydrates (see sugar article), so called because they consist of only carbon, hydrogen and oxygen. Carbohydrates in one form or another are among the most important constituents of all living matter. The two most common polysaccharides (carbohydrates consisting of many simple sugars) are cellulose and starch. Whereas cellulose is a structural material and is largely manufactured by plants to that end, starch is of importance in plant nutrition. It is found in all cereal grains, in the growing parts of plants, in fleshy roots and tubers.

Starch is the major constituent of the wheat grain and therefore of flour. **Table 1** shows the approximate composition of wheat and of white flour.

### *Breakdown of starch*

When starch is heated with a dilute solution of hydrochloric acid a breakdown into much simpler compounds occurs. If this is continued long enough the starch will be completely transformed into glucose, which indicates that starch is built up from combinations of glucose molecules. There are, however, many intermediate stages in the breakdown of starch to glucose and chief among the intermediate products are the dextrans or starch gums.

**Table 1 - Comparison of the composition of wheat and white flour**

	<b>Wheat</b>	<b>White Flour</b>
<b>Starch</b>	65-73%	68 - 74 %
<b>Proteins (gluten)</b>	8 - 14 %	7 - 13 %
<b>Water</b>	12 - 18 %	13 16 %
<b>Fibre (cellulose)</b>	2 - 3 %	less than 1%
<b>Fat</b>	1½ - 2 %	less than 1%
<b>Sugars</b>	2 - 3½ %	2 - 3½ %
<b>Mineral matter (ash)</b>	1½ - 2 %	0.5 %

The dextrins are gummy non-crystalline powders and differ from starch in that they dissolve in water. They are not fermentable by yeast. By boiling with acid they also are converted into the simple sugar glucose. The easiest way to distinguish between starch and dextrin is by means of iodine, which gives an intense blue colour with starch and a violet red colour with dextrin.

#### *Action of amylases*

Yeast requires sugar to produce carbon dioxide to inflate the dough. Flour contains small amounts of fermentable sugar, and the baker may add sugar when making the dough. As fermentation proceeds the production of maltose from starch by enzymes becomes important.

The enzymes concerned are called amylases (Latin *amylum*, starch), which dough temperatures can only attack starch granules which have been "damaged" in the milling process by roll pressure. On the other hand, damaged starch grains take up water and swell, so increasing the water absorption of the flour. If there are too many damaged granules an undesirably sticky dough results. Thus there is an optimum degree of starch damage in flour for best baking performance.

#### *Properties of wheat starch*

Starch occurs in wheat flour as almost spherical granules ranging from 0.002 to 0.05 mm in diameter. The large ones account for nine tenths of the total weight of starch but only one tenth of the total number of starch granules. When starch is commercially manufactured the large and small granules become separated, the large ones forming what is called "prime starch" - the cornflour you are familiar with. The fine granules are found in what is called "tailings", mixed up with chemically related substances called pentosan gums.

The granules are made up of tightly packed starch molecules, which in turn are made up of about 500 glucose units linked in a chain. When they are washed out from flour the granules form a fairly heavy white powder which is quite insoluble in water.

The starch molecules within the granule are not all of one kind. About one quarter of the weight is of a kind called amylose - this is made up of long chains of sugar molecules joined end to end like a string of sausages. The other kind, called amylopectin, is similarly made of chains of sugar molecules, but the chains are branched to produce a shape something like a

tree. This branched type, amylopectin, has the particular property of swelling in water, and forms the starch jelly in custard and blancmange.

One of the most important properties of starch is that at temperatures above about 70°C and in the presence of water the outer wall of the starch granule bursts and the starch inside forms a thick paste. This transformation from granular to a paste is known as gelatinisation. No deep seated chemical change takes place during gelatinisation.

### **Proteins**

The proteins, like the carbohydrates, are only found in living matter or as the products of living matter. In plants carbohydrate is associated with the protein, but in animals by far the greater part of the tissue solids are protein. Some examples of proteins are given in **Table 2**.

**Table 2 - Some common natural proteins**

<b>Name</b>	<b>Source</b>
Gliadin (one of the components of gluten)	Wheat grain
Glutenin (one of the components of gluten)	Wheat grain
Edestin	Hemp seed
Egg albumin	Egg white
Casein	Milk
Gelatin	Bone and cartilage
Haemoglobin	Red blood cells
Myosin	Muscle
Keratin	Hair and wool

### *Properties*

The most essential characteristic of proteins is that they contain nitrogen and generally sulphur, a fact which distinguishes them from the carbohydrates. Their molecules are very large and have to be broken down before they can be used as food.

Proteins are much more complex in their structure than carbohydrates. Starch can be broken down by acid to only one material, dextrose, which is the basic unit of the starch molecule. When a protein is treated in the same way it forms not one single compound but from 15 - 20 compounds which differ markedly in their properties. These building blocks of proteins are known as amino acids. So far, some 22 natural amino acids have been discovered and it is probable that the list is not yet complete.

### *Proteins and heat*

If heated, especially when wet, proteins usually undergo a chemical change called denaturation which does not reverse on cooling. Cooking of protein food usually has this as its object - for example the coagulation of eggwhite or roasting of beef. Proteins which have

been denatured usually lose elasticity, and become rigid, thus fixing the shape of the food. They also become more digestible, and more readily chewed.

Proteins vary widely in their stability to heat - wool may be boiled for hours without changing appreciably.

### *Gluten*

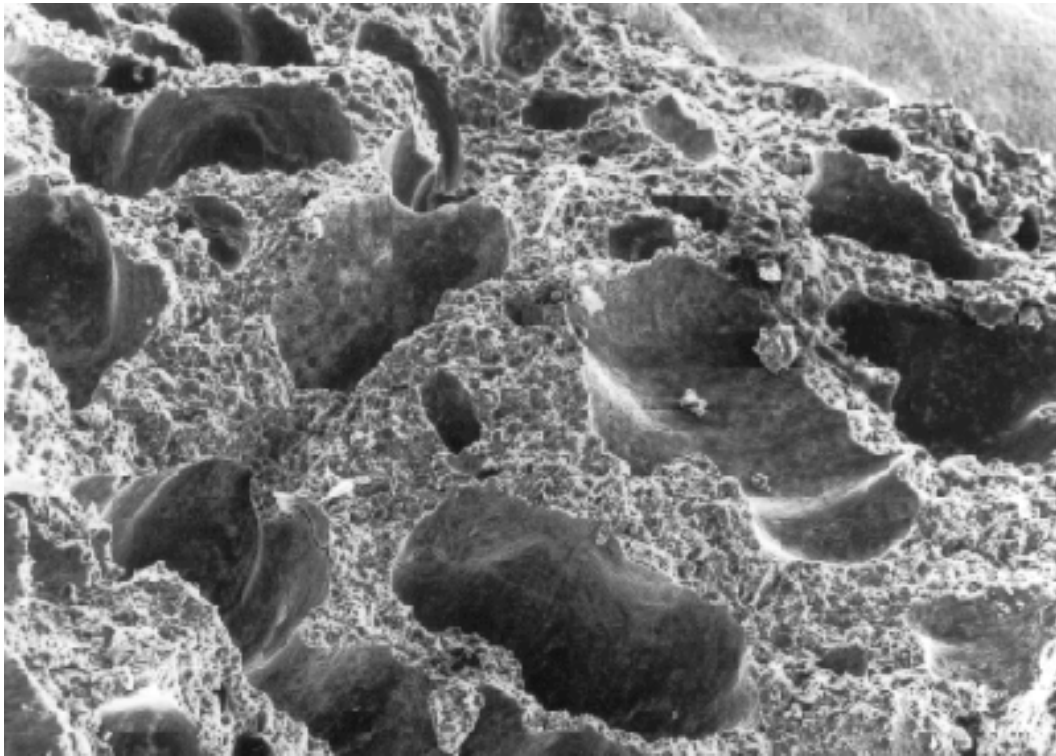
Gluten is the major protein found in wheat. A little of the protein of flour is soluble in water or salt-water, and these kinds of proteins we call albumins and globulins. They may not affect the baking quality of flour but this is a subject on which we don't know as much as we would like. The greatest part of the flour protein will not dissolve in water or salt-water and this part is known as gluten. It is the fact that wheat and rye contain gluten which makes them superior to other cereals for the production of porous baked foods. There are certain characteristic properties of gluten which makes it suitable for its purpose - it swells and holds water, it stretches but is somewhat elastic, and it is sticky.

The main function of gluten in dough during mixing is to swell and hold water, forming cells with strong, elastic walls which capture the carbon dioxide formed during fermentation. The starch granules do not swell at fermentation temperatures. However, at the higher temperatures of the oven the starch does swell to form a jelly structure and for this it needs water which it steals from the swollen gluten. At the same time as the gluten is losing part of its water it is setting, due to the heat, so that in the final bread we have two complete structures, one of starch and one of protein. Either of these can be dissolved away without the bread losing its shape. **Figure 2** shows the gluten-lined cells formed in fermented dough and **Figure 3** shows the gluten lattice of baked bread.

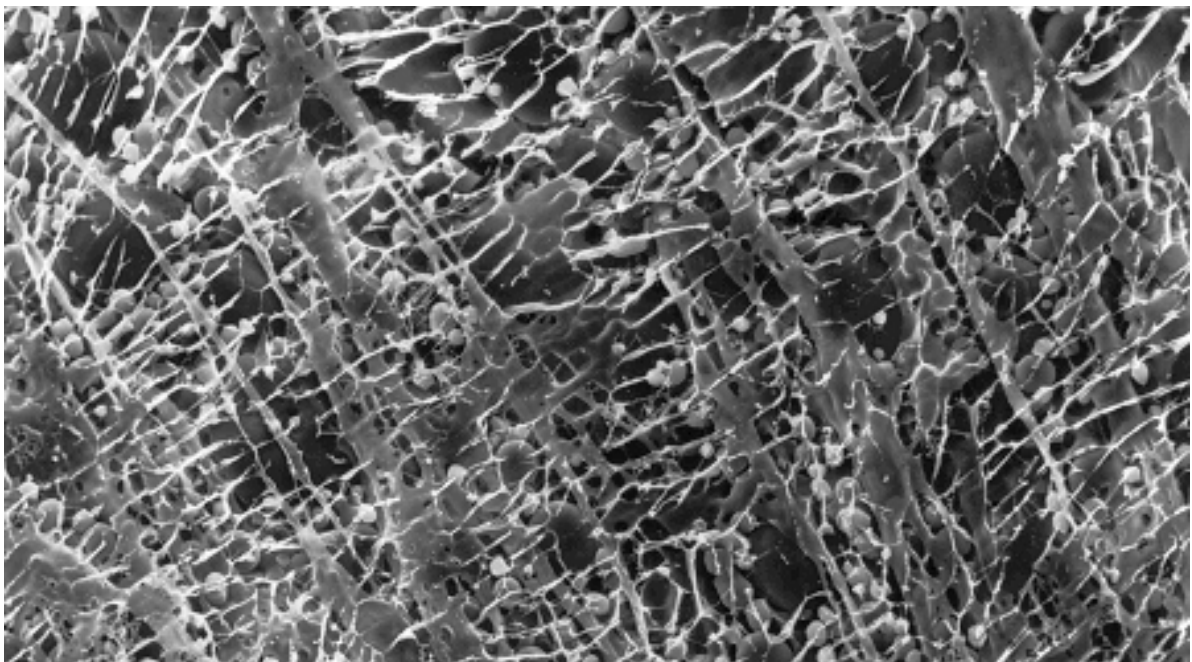
It has long been known that in a general way the baking quality of flour depends on the amount of gluten it contains - the more the better, within reason. But it has also long been realised that it is possible to have two flours with the same gluten content, one baking much better than the other. Once differences in the starch, enzymes, granulation and so on have been eliminated, we are forced to the conclusion that differences in quality of the gluten occur. The exact details of these differences are still unknown, but scientists are currently investigating the chemistry and physics of gluten through HPLC, electrophoresis and molecular biochemistry to gain a better understanding.

### *Gliadin and Glutenin*

In the text books dealing with cereal chemistry, a considerable amount of attention is devoted to the separation of gluten into two different proteins - gliadin and glutenin. Gliadin has the property, peculiar among proteins, of dissolving in 70% alcohol, whereas glutenin is insoluble. It was believed that the proportion of gliadin to glutenin was an important factor in determining gluten quality.



**Figure 2 - Fermented dough: large gas holes lined with gluten**



**Figure 3 - Strands of gluten forming a hard lattice in the baked bread**

Recent investigations indicate that the separation of gliadin and glutenin is a purely artificial separation and that in the wheat grain there is only one big complex type of protein molecule. It would be well to emphasise here that chemists still know comparatively little of even the simplest proteins such as gelatin and egg albumin, and that their knowledge of complex proteins of the gluten type is even more scanty.

### *Breakdown of proteins*

Just as starch can be broken down by boiling with acid to its simplest unit, dextrose, so proteins are broken down in the same way by boiling with acid. The analogy goes further. Starch can also be broken down by natural agents known as enzymes, and there exists in nature a group of enzymes known as the proteolytic enzymes, which do the same thing for proteins.

At the moulding stage the physical properties of the gluten become vital. Moulding involves stretching and stressing the dough, and the way in which the dough behaves under stress has a major effect on the bread produced.

The optimum state is called "mature"; an "immature" dough yields too readily and the stresses decay rapidly, and "overmature" dough does not yield, but tears. It is the condition of the gluten in the dough which is responsible for these differences.

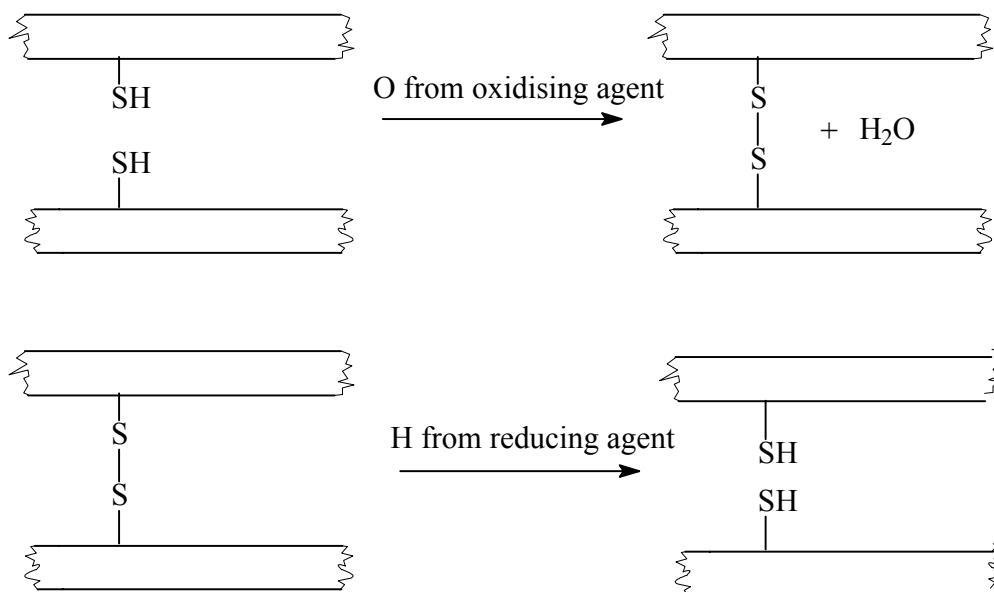
Gluten is easily obtained from a dough by gently kneading under a stream of water. Starch washes out, and a rubbery mass of gluten remains. An over-mature or "short" dough yields a tough, inelastic gluten, while an immature or "flowy" dough yields an extensible gluten. The starches washed from such contrasting doughs show no such difference in properties.

The changes in gluten properties which are termed "maturing" or "improving" have long intrigued cereal scientists. Maturing of flour may be brought about by age alone. This is very slow unless the flour is exposed to heat and high humidity. Gas treatment, using oxidising gases such as chlorine dioxide, is very rapid, and widely used in some countries but not in New Zealand. Doughs may also be matured by yeast. It will be noted that the most effective maturing agents are oxidising agents. Protein molecules are usually in the form of long chains of amino acids. When flour and water are mixed to form a dough there is microscopic evidence that mixing and working unite these chains to form sheets and strands which are virtually continuous throughout the dough mass, although no one molecule would extend further than a fraction of an inch. This is analogous to textiles where relatively short fibres can be woven into ropes or fabrics of any desired size. Obviously the physical property of the structure so built depends not so much on the strength of the individual units as on their adhesion or bondage one to the other. If the units are firmly bonded, any stress set up by working or moulding will remain for a long time. By contrast, if the units are held together by few or weak bonds, stress will decay rapidly. These two conditions correspond to over- and under-maturity.

### *Protein bonding*

Now what bonds between protein chains are possible? Chemists have long known that sulphur (S in the diagrams) can form such bonds. A sulphur-containing amino acid, cysteine, is one of the constituents of gluten, and the sulphur atom may either be linked to a hydrogen atom (H) or to the sulphur atom of another cysteine in another protein chain. The former is called the reduced form, the latter the oxidised. Reducing agents add hydrogen, oxidising agents remove hydrogen, usually to form water. Using these ideas, we see illustrated in **Figure 4** mechanisms by which oxidising agents such as bromate lead to bonds between chains, producing a maturing effect, and reducing agents such as glutathione (found in germ tissue) or sodium bisulphite (used in biscuit making) may break bonds, producing a greening effect.





**Figure 4 - Sulphur bonds forming between protein chains**

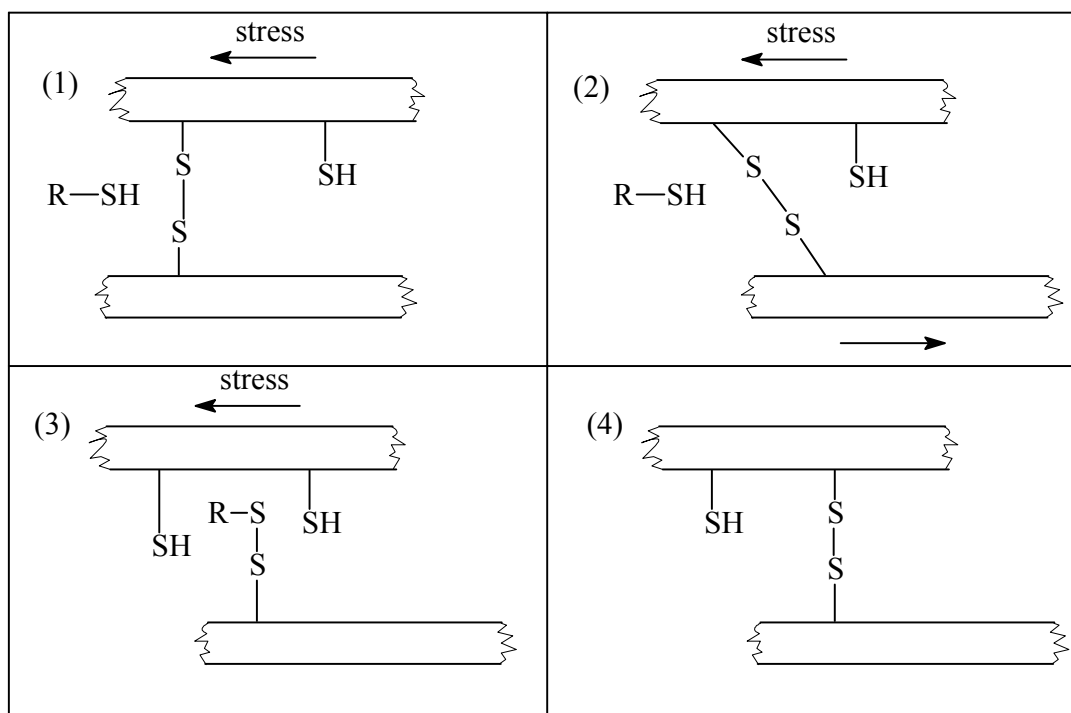
This "direct action" hypothesis is plausible, except that very low levels (a few ppm) of oxidising or reducing agents produce drastic effects. The "exchange" hypothesis is a better explanation: when dough is stressed, the S-S bonds may be opened by reacting with -SH groups, probably -SH on small, non-protein molecules such as glutathione, and then reformed by further reactions, thus allowing the dough to relax. No -SH groups disappear in the process.

The relief of strain by exchange is shown diagrammatically in **Figure 5**, which shows four stages:

1. Application of stress
2. Strain build up
3. Strain relief by opening of -S-S bonds
4. Reformation of -S-S bonds in new position.

Obviously any treatment which affects the number of -SH groups on the small molecules (R-SH in the diagram) will affect the rate at which the relaxation can take place. On this theory the effect of improving agents is to oxidise the R-SH to R-S-S-R thus preventing strain relief by exchange.

It is well known that doughs which are fully mature, or in other words, relax very slowly, are easily damaged by mixing or other vigorous treatment. This is presumably because the stresses rapidly build up to the point where rupture of the protein chains themselves occurs, causing irreparable damage.



**Figure 5 - Stress relief between moving protein chains**

## **BREAD MAKING**

Bread is the most important single product of wheat. Bread is made by mixing flour, water, yeast and salt to form a dough. This dough becomes porous as it is inflated by gas produced by the yeast. The dough is "divided" into loaf sized pieces, "moulded" into the appropriate shape, "proved", i.e. allowed to inflate further, and then baked.

### **Ingredients**

Bread consists of flour, water, yeast and salt, as well as a variety of other ingredients. The roles of flour and yeast are discussed in the article on baking, but the function of the other ingredients are listed here.

#### *Salt*

Salt has two effects on bread: it improves the flavour (both by providing its own and bringing out others) and strengthens the gluten network, improving the dough consistency and helping to prevent the escape of gas.

#### *Sugar*

Yeast uses the sugar as food, and after the yeast dies the remaining sugar sweetens the flavour of the loaf and 'browns' to produce the crust (see baking article).

#### *Acidity regulators*

A slightly acidic bread is less susceptible to mould and bacterial growth, and to this end vinegar, acetic acid or citric acid are commonly added to bread.

#### *Fats and emulsifiers*

Although the germ of wheat is relatively fatty - it contains about 10% of fat - flour contains only about 1% of fat. There is conflicting evidence whether this natural flour fat is of

importance in baking. However the value of added fats in softening the crumb of bread and increasing bread volume (by assisting in trapping gas bubbles) is not in doubt. Fats also improve the flavour of bread.

#### *Milk*

Milk softens the crust of bread and moistens the crumb.

#### *Malt flour and malt extracts*

Malt flour is the flour made from sprouted barley. It is rich in  $\alpha$ -amylase, the enzyme that converts starch into sugars, and so the addition of malt flour means that some of the starch present in the wheat flour is converted to sugars on which the yeast can feed. In addition, malt flour changes the flavour and colour of the bread.

#### *Flour treatment agents*

These are used to strengthen the dough (see *protein bonding* above) so that it rises quicker and stays risen longer. The most common flour treatment agent used in New Zealand is vitamin C, although potassium bromate could also be legally used until 1996.

#### *Enzymes*

The most common enzyme to be used is the naturally present  $\alpha$ -amylase (see above).

#### *Soyabean flour*

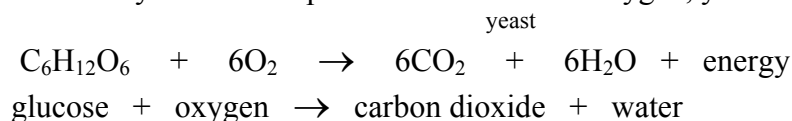
This is a source of fat and enzymes. The fat functions as given above, and the enzymes are such that they react with oxygen in the air to bleach the bread. This makes a white, rather than yellow, crumb.

#### *Gluten flour*

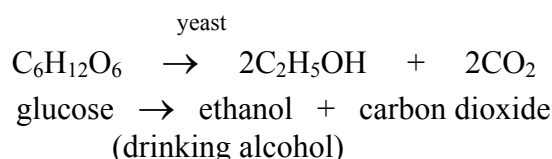
Gluten can be removed from flour by washing the starch out with water. The gluten thus produced can be added to other flours that have insufficient gluten. Gluten is commonly added either because the flour comes from poor wheat kernels or because the bread includes such things as kibbled wheat which need an extra strong dough to support them.

### **Chemical changes occurring during bread production**

The basic reactions that occurring during the mixing, rising, kneading, proving and baking of bread are the reactions of yeast. In the presence of sufficient oxygen, yeast reacts as follows:



The energy released helps the yeast to continue growing, and the carbon dioxide is the gas that causes the bread to expand. In the presence of insufficient oxygen, the yeast catalyses the following reaction:



The ethanol later evaporates off.

During this time, the physical processes of mixing are very important. During the initial mixing, the ingredients are evenly distributed and some oxygen is mixed into the loaf. This ensures that sugar and starch, the enzyme that breaks down the starch, the yeast and the oxygen are all in contact with one another throughout the mixture. The dough is then left to react, and carbon dioxide is formed. After a sufficient quantity has been formed the dough is kneaded. This results in the larger bubbles of CO<sub>2</sub> being broken up so that all bubbles are of roughly the same size, and then distributes the bubbles evenly throughout the dough. When the dough is left to rise a second time, the new CO<sub>2</sub> that is formed largely goes into these same bubbles, causing them to expand, rather than creating new ones.

The dough is now ready to be baked. Between room temperature and 46°C the yeast continues to work, and works faster and faster until it dies at 46°C. At the same time CO<sub>2</sub> that had been dissolved in the bread mix becomes gaseous and continues to expand the bread, while the alcohol evaporates off. Between 46°C and 75°C (when it dies) the  $\alpha$ -amylase continues to produce sugars which sweeten the loaf and are involved in some later reactions. From 60°C onwards the starch granules begin to swell. However, they do not expand to the point at which they burst (causing gelatinisation as described above) because insufficient water is present. From 74°C onwards the gluten strands become semi-rigid, at 100°C the water is driven off and from 160°C onwards the sugars react in browning reactions to produce the crust. However, although the surface of the bread can get to over 200°C, the internal temperature doesn't usually rise above 98°C and so some water is retained within the bread.

Once the crust is formed the bread is cooled down to room temperature, sliced if required, and packaged.

#### *Importance of starch in the staling of bread*

One further important change that bread undergoes over time is the physical process of staling. Crumb staling appears to be closely related to the changes taking place in the starch of the loaf. Fresh bread has its starch essentially in the form of the swollen granules already mentioned. Each granule has the appearance of a hollow bag filled with liquid, which is composed of starch and water. The gluten forms a network holding these starch granules together.

The starch in the bread as it comes from the oven is in an unstable condition, with the molecules arranged in a particular pattern which can be shown by special techniques using X-rays. Now at room temperature this pattern is not stable, and slowly the molecules re-arrange themselves into another pattern which they prefer and which cannot hold as much water as original. The granules shrink during this transformation, become harder, less elastic and drier as the water is forced out. This re-arrangement is the process we call "staling", which is different from a simple drying of the bread.

The change is a reversible one, i.e. by reversing the conditions which brought about the change, the starch will revert to the same form as when the loaf left the oven. This explains why a stale loaf becomes much improved if it is heated for a short time in the oven.

The change in starch brought about by cooling can be prevented by not allowing the bread to drop below about 50°C. In this way, if special precautions are taken to prevent the loaf drying out and the growth of moulds, bread may be kept fresh for extended periods.

Alternatively, by rapidly cooling the bread to -10°C the starch can be literally frozen in its high temperature pattern, and the bread remains fresh for weeks. This is because the starch molecules cannot re-arrange themselves as their mobility is severely restricted by the solid water within the grains. Note, however, that some staling occurs while the loaf is passing through the 50° - 0°C region, during both freezing and thawing. Note also that bread stales fast at around 4°C - the temperature inside a fridge.

**Table 3 - Approximate nutrient content of 100g of bread**

	Bread type							average adult ADI*
	White	Whole meal	Wheat /Rye	Multi-grain "heavy"	Multi-grain "light"	Italian style	Wheat/oats	
<b>Protein / g</b>	7.3	8.0	9.1	7.7	8.8	9.6	9.6	57.5
<b>Thiamin / mg</b>	0.37	0.32	0.35	0.24	0.35	0.44	0.38	1.1
<b>Niacin / mg</b>	1.74	0.84	0.84	1.13	0.97	0.96	0.99	18
<b>Riboflavin / mg</b>	0.02	0.09	0.07	0.08	0.06	0.03	0.06	1.7
<b>Iron / mg</b>	1.01	1.75	1.73	1.61	1.4	1.38	2.1	11
<b>Calcium / mg</b>	40.2	32.9	39.4	49.7	39.3	39.6	48	600
<b>Energy / kcal</b>	216	198	207	189	230	232	222	2330

\* The Adequate Daily Intake (ADI) figures are the averages of figures for adult men and women produced by the Nutrition Advisory Committee of New Zealand in 1983.

### **The nutritional value of cereals**

Cereals are widely known as a valuable source of fibre and as an important energy source. The complex carbohydrates in cereals are much less energy dense than fats, meaning that excessive energy is unlikely to be consumed. Even if it is, the body can simply oxidise excess carbohydrates, while excess fats have to be stored. A diet rich in cereals leads to lower levels of heart disease, obesity and a variety of other illnesses. In addition, cereals contain small amounts of many important nutrients. A summary of those found in bread is given in **Table 3**.

#### *Proteins*

Proteins are broken down by the body into their constituent amino acids which are then used for rebuilding protein structures in the body. Their most notable use is in muscle repair.

#### *B group vitamins*

Thiamin, niacin and riboflavin are all B vitamins. They are involved with breaking down carbohydrates to release energy and then making use of this energy.

### *Minerals*

Calcium is needed for maintaining and repairing bones and teeth, and iron, in the form of the protein haemoglobin, carries oxygen around the body.

## **EXPERIMENT**

Mix 25 g of flour with enough water (about 15 ml) to make a firm dough. A pestle and mortar may be used, or a stout stirring rod or spatula and a yoghurt container. Glass stirring rods and glass beakers are very likely to break.

If possible allow to stand, covered with water to prevent drying out, for up to an hour. This standing time may be reduced to zero if necessary, but standing facilitates subsequent operation.

Knead the dough under a very slow running tap, over a vessel such as a 2 litre ice cream container. Knead very gently at first, and more vigorously later. Continue kneading until the washings are near clear. When the 2 litre container is full set it aside and allow the rest of the washings to go down the sink.

The residue is gluten. Weigh this, and assuming it is two thirds water, calculate the amount of dry gluten in the original flour. Take a piece of gluten, about the size of a small walnut, and put it in boiling water for 20 minutes. Note any change in its properties. Is this analogous to the reactions of egg white?

Let the milky washings in the bucket or basin stand overnight and examine the sediment. This is starch (test with iodine). Examine it under a microscope if one is available. Take a dessertspoon of this wet sediment, add five dessertspoons of water, and bring to the boil while stirring. Allow to cool noting any change, and examine again under a microscope if possible.

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