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Sourdough Bread

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1.0 Introduction and Origin of Sourdough Bread

By Irene McIntyre

The term 'sourdough bread' refers to bread leavened with a sourdough starter. A sourdough starter is a natural leaven – a mixture of grains and liquids usually flour and water inhabited by so called "wild" yeasts and bacteria which leaven and flavour the bread dough. Bread can be made with either baker's yeast or alternatively sourdough for dough leavening. In comparison to bread prepared with baker's yeast, the sourdough breads are characterized by moist, dense grain, and rather chewy texture. Spontaneous sourdough consists of flour and water blended together to make a "sponge". This "sponge is left at room temperature for several hours (see figure 1); endogenous fermenting microorganisms produce metabolites that affect the characteristics of the dough. The addition of new flour and water to the dough, defined as backslopping, allows a composite ecosystem of yeast and lactic acid bacteria to take place within the dough, giving it its typical sour taste. The yeast is mainly responsible for the production of CO2, and the lactic acid bacteria are mainly responsible for the production of lactic and/ or acetic acid; both microorganisms are responsible for the production of aromatic precursors of bread, (Friberg *et al.,* 2005). Furthermore, the technological performance of the dough and the nutritional properties, aroma profile, shelf life and overall quality of the bread are generally affected by the metabolic activity of these sourdough microorganisms. The use of sourdough in bread making improves loaf volume and flavour, delays staling, and inhibits the growth of spoilage fungi and bacteria. Today, sourdough bread is produced mostly in retail or artisan bakeries for a wide variety of specialty products, whereas it is not used in the mechanized baking industry, in which baker's yeast is the main leavening agent. San Francisco bread is the most famous sourdough bread currently produced in the United States, (Rayner, 2009).

Figure 1: Sourdough starter. Spontaneous sourdough starter prepared with durum wheat and approximately 70% water. The production of CO2 is shown by small points on the surface.

A brief history of sourdough breads

As sourdough involves a spontaneous fermentation process, it can undeniably be considered the ancient form of bread leavening. It is generally understood that the use of sourdough in bread leavening began in ancient Egypt in approximately 3000 BC and from there extended gradually to Europe, throughout ancient Greece and the Roman Empire until the present.

Wheat and other grains cultivated in the Nile River Valley were used in ancient Egypt to manufacture leavened breads on a large scale basis-enough to feed thousands of people per day. The ancient Greeks soon became familiar with leavened breads as a result of increased importation of these wheat grains from Egypt. The Greeks subsequently began to make bread and contributed remarkable improvements to the technology and baking equipment. The Romans too became avid bread eaters, where initially freed slaves who became professional bakers soon became public officials. However, as a consequence of the barbarian migration period in Europe, bread was no longer accepted as the primary food by barbarians and subsequently industrial bread manufacturing vanished. The knowledge of sourdough bread survived in the monasteries until the twelfth century when the vocation of baker reappeared in France. After the middle ages, the technology of bread made new advancement especially in northern Europe where breweries were prevalent, the barm obtained from beer brewing was recognized as a substitute for sourdough in the leavening process. At present in northern Europe, sourdough is used primarily in the baking process of rye flour.

Since the nineteenth century, baker's yeast which is also known as compressed yeast has essentially replaced sourdough in the leavening of bread, (Preedy *et al.,* 2011). The developing popularity of baker's yeast was attributed to its greater suitability for the specifications of modern baking processes, as a rapid and uncomplicated leavening process, and the shift to mechanized bread

production. In fact, the sourdough baking process is time-consuming and requires a long fermentation time, (Preedy *et al.,* 2011).

However, in recent years, sourdough bread has grown in popularity due to increased consumer demand for bread with pronounced flavour, high nutritional value, healthy properties, prolonged shelf life and less additives; and as a result, the traditional aspects of sourdough breads have become attractive to consumers, (Rayner, 2009). As sourdough bread has developed over the years many different variations and cultural differences have developed, due to this fact a further look into these differences are needed.

2.0 Cultural differences and variations of sourdough

By Clara Kelly

Sourdough is a common food over a very wide geographical area. It is eaten almost everywhere that cereals are available and is now being consumed more commonly in regions, such as south east Asia, that have not been traditional bread consumers.

The American sourdough production process originated from San Francisco and it uses microorganisms and procedures different from those used in Europe. American sourdoughs also differ from European sourdoughs in that they are usually pan loaves with some fat and sugar added, (Kulp, 2003).

Each bakery's mother dough, also known as the mother 'sponge' has been in continuous use since the respective bakery's founding. It can be said that San Francisco's sourdoughs are the oldest inhabitants. The yeast strain, *L.Sanfranciscensis* has to date only been found in sourdough .Moreover, it populates around the world and is used to make west- phalian pumpernickel in north west Germany, Italian panettone, and of course the famous San Francisco sourdough bread, (Renneberg, 2008). However the yeast strain that dominates most in San Francisco sourdough cultures is *Candida millers,* which cannot utilize all the sugars in the dough. Yet, it is much more tolerant of acetic acid than other yeasts (most yeasts are tolerant of moderately acid environments, but remain sensitive to acetic acid). The rising power of the San Francisco culture is less than that of commercial yeast, and less than that of some other leaven breads, but bakers compensate for this characteristic by increasing fermentation time and proof time to 8 hours, (Wing *et al.*, 1999). San Francisco sourdough bread is usually made of high-protein (strong) wheat and as a result the modest rising power of the culture has a hard time overcoming the power of this gluten, (Renneberg, 2008). The long time required for the dough to rise encourages acid production, so the finished bread has a pH of 3.9 (very acidic).

Desem is the name of a superb kind of naturally fermented whole wheat bread which has been produced for many years in Belgium, (Wing *et al.*, 1999). Desem bread is as distinctive as San Francisco sourdough. Desem cultures are always started from fresh organic wheat flour. Thus, Desem is a type of natural leaven that maintains a close connection between the farm, the grain, and the finished loaf. The Desem flour itself is also made with strong wheat flour, which by nature is not as mechanically strong as white flour. Desem dough is fermented slowly at a low temperature, and then proofed at an elevated temperature for 90 minutes (Wing *et al.*, 1999). The rapid proof produces bread much more acidic (4.7 pH) than commercially yeasted dough but also prevents the loaves from going flat, even though the gluten in fresh flour is weak. The flavour of the finished bread is nutty and sweet without a pronounced acid taste.

Most bread is made from wheat, although in Finland and north-eastern Europe bread containing rye is common. Rye is a popular cereal used in the production of sourdough; it contains usually 30-70% of dark or light rye, (Wing *et al.*, 1999). The structure of the dough comes from the viscosity of the rye pentosans as well as any gluten contained in wheat flour that is added. It involves moderate

duration leaven, fermentation, and proof stages compared to San Francisco and Desem sourdough bread resulting in a moderate pH and consequently a moderate sour rye flavour. Therefore, it is evident that breadmaking practices and processes frequently vary on a geographical or cultural basis.

The production of bread especially sourdough bread occurs at differing levels of sophistication from simple earthen pots and ovens to large computer-controlled industrial bakeries. Thus, a single geographical area may have a range of products produced with varying levels of sophistication. Different manufacturing processes may be more commonly encountered in some countries than others. In Great Britian, 78% of bread is produced in plant bakeries, (Wood, 1998). Some of the plant bakeries can produce several thousand loaves each hour. However small-scale bakeries in which bread is made and sold on the premises dominates the market in many countries, this is especially seen in many regions of France and is a big part of the French culture. Italy is another example where 75% of products are produced by small retail (craft) bakeries, (Wood, 1998). The baking of bread on a large scale in societies demanding high rates of productivity has created an industry to produce yeast for bread making, for instance producers of baker's yeast align themselves strongly with the food industry, despite being part of the fermentation industry in technology.

3.0 Raw Materials of Sourdough Bread

By Daniel James

Sourdough is made from flour and water, which starts to ferment spontaneously and which is allowed to ferment for a particular time at a certain temperature. Flour contains lactic acid bacteria, which will develop in the mixture and which will acidify it. A sponge is made from flour, water and commercially available yeast. As a sourdough it is held for a specific time at a specific temperature.

The primary function of yeast is to produce a carbon dioxide gas, which is responsible for expanding the dough and in the early stages of baking. Yeast works best at slightly acidic conditions. A pH ranging from 4.5-6 is ideal. Bread dough's are generally in the region of pH 5.5 so in bread making the pH isn't a massive concern. However some ingredients used in baking, such as mould inhibitors in some bread improvers, lower the pH of the dough and do have a retarding effect on yeast fermentation, (Haegens, 2009).Carbon dioxide cannot form a gas bubble on its own it requires a nucleating site. In bread dough the nucleating sites are provided by the nitrogen gas bubbles trapped in the dough during mixing. The yeast has used up the oxygen from the air. During proof stages the carbon dioxide goes into solution until the solution is saturated and then any more carbon dioxide generated makes its way into the nitrogen gas bubbles, which grow in size, and the dough expands. The more yeast and the warmer the temperature the faster the expansion, (Haegens 2009). To sum up, the dough is aerated by the action of the yeast. The little cells ferment the dough, and produce tiny bubbles of gas inside it. As a result, the dough gets bigger, and rises. Thus when the dough is baked, a 'bold' loaf exists, and is light and airy; when you cut it you can see all the tiny holes formed by the gas, so that it looks like a sponge.

Bread dough is roughly 40 % water. Besides the amount of water we are using, its quality plays also an important role. Water is an essential ingredient. In a bakery product all ingredients interact among one another at the molecular and atomic levels to give the final texture, flavour, taste, aroma, character, palatability and mouth feel.

In making dough, the consistency depends clearly on the amount of water used in making it. The amount of water needed depends on the quality of the flour and the kind of bread being made. Water is essential to form the gluten and give the dough consistency. It is also the solvent or medium for substances like sugar and enzymes that are indispensable for the fermentation. Water has also an essential role in homogenizing all the substances throughout the dough during kneading. The water is also needed for swelling and gelatinisation of the starch. This in its turn improves the

easy digestion of the bread. Finally the distribution of the heat through the bread during baking is done by water in the dough.
By far the most interesting raw material used in this bread is the starter, used to leaven the bread. The use of wild yeast and bacteria is described in the following section.

4.0 The Starter Culture
By Jennifer Smith

For the production of sourdough bread, a starter culture is required to initiate the fermentation process in this unique bread. This is considered an important technical property which is fundamental in the production of the bread.

The sourdough bread can be started by either adding a piece of mother sponge, which is mature sourdough, or by adding a defined starter culture, (Hansen, 2004). Starting the process with a starter culture will result in spontaneous fermentation. The sourdough culture is a mixture of flour and water. The flour naturally contains yeasts and bacteria, and when it is added to water, a proportion of the starch and gluten in the flour is broken down by enzymes in the flour. This results in the formation of sugars and some amino acids which the yeasts and bacteria feed on and metabolise (Renneberg, 2008).

The micro floras which are found in the fermentation process are the homofermentative and heterofermentative lactic acid bacteria (LAB). Lactic acid is produced by both types of LAB, however, the heterofermentative LAB produces a mixture of lactic acid and acetic acid, resulting in good flavour and aroma, for which this LAB is responsible, (Cappelle and Decock, 2005).

The traditional San Francisco sourdough bread contains a certain strain of LAB known as *Lactobacillus sanfraniscensis*. This is the main LAB found in the bread, which has heterofermentative properties. It grows and ferments best on maltose resulting in a sharp acetic acid flavour, (Cappelle and Decock, 2005).

The heterofermentative LAB use the Embden-Meyerhof-Parnas pathway and then the phosphogluconate pathway to ferment the sugars available, (Corsetti *et al.,* 2005). The glucose is dehydrogenated resulting in 6-phosphogluconate, which is then decarboxylated to form pentose-5-phosphate. Phosphoketolase cleaves onto this and forms glceraldehyde-3-phosphate and acetyl phosphate, (Kulp, 2003). The acetyl phosphate is reduced by acetyl CoA into ethanol. The acetyl phosphate can also be reduced by acetyl CoA and then further by acetate kinase into acetic acid. The glyceraldehyde-3-phosphate is reduced via the glycolytic pathway into pyruvate, which is then further reduced by phosphogluconate dehydrogenase into lactic acid, (Kulp, 2003).
Homolactic fermentation takes place by glycolysis or the Embden-Meyerhof-Parnas pathway. The glucose sugars available to the bacteria are phosphorylated by glucokinase, which is dependent on ADP, resulting in fructose-1,6-diphosphate, (Kulp. 2003). This is then further split into dihydroxyacetone phosphate and glyceraldehyde-3-phosphate, by the action of fructose-diphosphate aldolase. The glyceraldehyde-3-phosphate is converted into pyruvate, which is then further reduced by lactate dehydrogenase into lactic acid, (Kulp, 2003).

The natural occurring yeasts that are in the flour give rise to some alcohol fermentation. This process produces 1 mole of both ethanol and carbon dioxide per mole of glucose available to it, (Kulp, 2003). The fermentation process follows the Embden-Meyerhof-Parnas pathway. The

reaction involves the breakdown of saccharides that are present in the flour. The resulting glucose can then be metabolised by glycolysis, whereby the glucose is phosphorylated by glucokinase into fructose-1.6-phosphate. It is split into dihydroxyacetone phosphate and glyceraldehyde-3-phosphate. The glyceraldehyde-3-phosphate is converted into 2 moles of phosphoenolpyruvate, which is then reduced by pyruvate kinase into 2 moles of pyruvate. The pyruvate is broken down into acetyl CoA and acetaldehyde by acetaldehyde dehydrogenase. The acetyl CoA goes into the Krebs citric acid cycle where it produces carbon dioxide. The acetaldehyde is reduced by alcohol dehydrogenase into ethanol, (Kulp, 2003).

The starter dough will become sour and create a bad smell at first, as many microorganisms begin to grow. However, after feeding the starter repeatedly with small amounts of fresh flour and water, a symbiotic culture develops which is balanced, (Renneberg, 2008). The sourdough starter will contain a stable symbiotic culture of lactic acid and yeast. The most common found in starter cultures are the *Lactobacillus sanfraniscensis* and the yeast, *Candida humilis*, (Renneberg, 2008). The active sourdough starter is then ready to be used in the bread baking process.

5.0 Process and Technology
By Sarah Morris

Once the sourdough starter has been produced and is ready to be used the process can begin. The main function of the starter is to leaven the bread and produce more aerated bread, (Chavan & Chavan, 2011). The starter is added to flour, water, salt and vegetable oil. It is mixed together to form a dough and then left at room temperature or warmer, about 24°C and allowed to ferment for up to 18 hours. In industry it can be given

"Floor time of 30 min at +28 1C and relative humidity of 76%", (Katina et al., 2006).

It is done this way as there is would not be viable to leave for 18 hours. At this time the dough will double in size, in industry this step is very important as it is the step that produces the large air bubbles that sourdough bread is famous for. Once the dough has doubled in size it is it is folded or kneaded to knock out some of the air, the technology developed for this step is simply to mould the breads mechanically into tins as this knocks out the air. At this stage comes the proofing, whereby the dough is left to rise for 2 hour, in industry however this is reduced to usually 60 min at +35°C, RH 75%, (Katina et al., 2006). At this step the dough is fermenting to produce a pleasant aroma. This fermentation step was reduced or even excluded during the mechanism of baking as it was not compatible.

"To avoid this complex processing in the bakery, specialised companies supply dried sourdoughs to the bakery industry", (Decock & Cappelle, 2005).

Decock & Cappelle (2005) discuss how gas chromatography and mass spectrometry detected that sourdough bread produces more volatiles when compared to reference bread, therefore it was necessary to include these fermentation steps to produce the kind of flavours and aromas that have become so popular. After proofing the dough is baked, Wink (2007) states that the crispy crust associated with sourdough bread is developed from moisture being present during the baking at a very high temperature. Wink (2007) recommends baking at 246°C with a container of water in the oven and to sprinkle with water throughout baking. The technology developed for this part of the bread making is a mixture of automated liquid dosing systems and continuous belt lines along with tunnel ovens, (Decock & Cappelle, 2005). Chavan & Chavan (2011) discuss that the baked sourdough bread must be cooled for 2- 6 hours as it is to be packaged. Decock & Cappelle state that

further automation reduces this time by using spiral coolers. Further technology has been developed such as

"Automated slicing, packaging machines and robot arms who place the final product on pallets", (Decock & Cappelle, 2011).

Even with these automatic steps in place it is still a lengthy process that some bakeries find hard to deal with large orders and cannot produce enough bread in one day. For these reasons other methods have been developed, Decock & Cappelle (2011) talk about unproofed cooled or frozen dough. In this process the baker cools the dough down to -2°C to reduce the fermentation speed to a minimum and leaves it over night, reducing work needed in the night.

"It was back in the late 1970s, industrial bakeries started supplying unfermented frozen dough for bake-off to supermarket chains, retail bakeries, food service and institutional users", (Biebaut, 2003).

Another step forward in technology to help ease the work on the bakeries, making sourdough production easier to handle was developed in the 19+90's and was prefermented frozen doughs, (Decock & Cappelle, 2011). This technology allows fermented dough to be frozen and taken straight from the freezer to the oven; the amount of fermentation varies between 20% and 100%, (Decock & Cappelle, 2011). However it is recommended that some products be thawed before transferred to the oven, therefore adding more time to retailers so,

"In the search for convenience, the final fermentation step is even skipped by offering to the bake-off market ready-to-bake frozen products", (Decock & Cappelle).

This ready-to-bake unfermented frozen technology means retailers no longer have a need for a proof- box, however steam ovens and longer baking times are required. Other technologies now in place are also discussed by Decock & Cappelle (2011) and included Par- Baked technologie, whereby bread is partly baked in the factory and then finished off in retailers to have fresh bread. Long shelf life and thaw and serve breads have been developed, however there are some characteristics of the bread affected such as softness and elasticity which may avert consumers to buy another bread, (Decock & Cappelle, 2011).
As technologies have developed, and even failed it has become apparent that consumers are always looking for tastier and more flavoursome bread, characteristics that sourdough never fall short in. It is worth further researching into the flavours and tastes of sourdough bread to get an insight into why this ancient bread is still popular today and has not fallen by the wayside when newer and easier bread technologies have been developed.

6.0 Flavour and Taste of Sourdough Bread
By Fiona Bourguignon

Sourdough breads have usually different textures and flavors than yeast leavened breads. In this section we will compare the differences of aroma, texture and taste of the sourdough bread made with rye flour and wheat flour. Currently, it is not ordinary to buy sourdough bread, however when people want to buy some, they are looking for a very precise taste and aroma. For example, sourdough bread has been estimated to be only three percent of all the bread manufactured in France, (Katina *et al.*, 2006).
When consumers buy food, it is for eating but for enjoying it too. The taste and the aroma of the products make them to feel good and to appreciate the meal. According to Blanshard *et al.*, 1985, bread taste and flavor are the result of concerted effects of the components in the dough, the aromas developed during the fermentation and the reactions which occur the baking. At the present time, more than 99 volatiles are known to be present in sourdough rye breads. Also, many parameters can modify aromas generated during the baking, such as the starter cultures, the fermentation, the flour, etc., (Kirchhoff & Schieberle, 2001).

Raw material is one of the major factors which give to bread its uniqueness. The most important is the flour which brings components which can be damaged to give taste and texture to the bread. If these primary components are different, the bread will not be the same. The major precursors of flavors and aromas are proteins: they increase the intensity of overall flavour, the roasted flavour and the intensity of the aftertaste. They have a direct impact on the quality of the bread: according to Arendt *et al.*, (2007), when proteolysis occurs, compounds are released and they will act to form aroma volatiles when the bread will be baked.

According to Gänzle *et al.*, (2008), the way cereals proteins are degraded affect the texture and the flavors of the sourdough bread. The acidification leads to the release of substrate highly accessible. For the wheat doughs, the rheology and the resulting loaf volume are mainly determined by gluten proteins. Rye flour is poor in gluten proteins; it's why this flour needs to be pre-fermented during the sourdough stage. During the baking, precursor such as amino acids, fatty acids and phenolic compounds are converted into flavour-active components, (Salim-ur-Rehman, 2006).
The second ingredient used to make bread is the water. According to Gaines & Donelson, 1982, the cake expansion is influenced by the quantity of water added to make it. During the baking, the differences of the expansion of the dough and liberation of gas, will give to the bread different tastes. Rye flour has a better capacity of water absorption than wheat flour, this is due to the high levels of pentosans including in the rye flour. If the water-binding is better in rye dough, texture will be different to other sourdough bread made with wheat, (Cauvain, 2000).

Bread made without salt is insipid, it's why it is firstly used in bakery: to produce appetizing and aromatic bread. Most rye breads contain a high percentage of salt: usually between two and three percent (dry weight basis), (Matz, 1989). Sweeteners are seldom included in rye dough; however it's ordinary to include diastatic malt syrup in the sours: one percent to ten percents in the lighter types. Caramel color is used in all recipes to have a darker color, bakers add as much as ten percents (full weight bearing) of caramel color.

During the fermentation, bacteria and yeasts present in the dough are responsible for a part of the aroma that we can find in the final product: acetic acid, lactic acid and other organic acids can be detected in the bread, (Blanshard *et al.*, 1985). Heterofermentative lactic acid bacteria produce ethyl acetate principally and certain alcohols and aldehydes. For their part, homofermentative lactic acid bacteria synthesize diacetyl and other carbonyls. Usually, wheat sourdough breads release fewer flavors compounds compared to sourdough made with rye bread. According to Hansena &

Schieberleb, (2005), this fact can be explained by the high extraction of the rye flour. Moreover, some fermentation products can enhance the rate of browning reaction and to modify the texture of the bread. The list of aroma components for which baker's yeast has been reported to be responsible is almost without end. Each ingredient brings its own flavors and when the fermentation happens, micro-organisms react differently with each of them, according to the process, etc.

According to Matz, (1989), the principal acid producing genus of bacteria found in sourdoughs is the lactic acid organism *Lactobacillus*. Some *Enterobacter* and *Citrobacter* have been found and the yeasts found in sourdoughs are generally *Saccharomyces*. It is generally considered that in sourdoughs, the ratio of lactic acid bacteria to yeast should be 100:1 for optimal activities. The richness of the bread, in flavor is also due to bacterial souring of the initial sponge through air contamination. Different strains of *Lactobacillus* were found in rye and wheat sourdough. We could suppose that each species produces different substances which can affect the flavors, textures and color of the bread and lead to a unique bread. Acidification leads to increase water binding capacity of the dough, because of its effect on the starch granules. In rye dough, acidification makes the dough more elastic and extensible and give to the bread its characteristic acid flavour notes, (Arendt *et al.*, 2007). Moreover, it induces proteolysis, but flavors can be undesired, such as pungent flavor. It have been demonstrated that sourdough fermentation of wholemeal rye with characteristics flora (lactic acid bacteria and yeasts) increase the level of free phenolic compounds, which are higher than in wheat. Phenolic acids can be associated with color and sensory characteristic of the sourdough bread. The high level of phenolic compounds in the rye flour gives the intense aftertaste and bitter flavour which are characteristic flavors of the rye sourdough bread, (Arendt *et al.*, 2007).
According to Salim-ur-Rehman, (2006), two categories of flavour compounds are produced during sourdough fermentation. Non-volatile are organic acids and they acidify the dough. The volatile compounds include alcohols, aldehydes, ketones, esters and sulphur. Acetic acid is present in a very high concentration in rye bread crumb (1.7 g/kg), 3-methylbutanol, butanoic acid, vanillin, and 2- and 3-methylbutanoic acid are also present in high concentrations (values ranging between 1 and 3 mg/kg). 2, 3-butandione is suggested to directly influence the flavor of the bread crumb, (Kirchhoff & Schieberle, 2001). Phenolic acid (total concentration between 136.6 and 65.3 mg/100 g) and Alkylresorcinols (between 143 mg and 72.6 mg/100 g) are also mainly present. Lignans are a minority (about 2 mg/ 100 g) and the most abundant one in rye flour is syringaresinol. In wheat, the level of syringaresinol is only one-third of that in rye. The flavour-active phenolic acids are the non-bound and the most abundant in rye flour are sinapic and ferulic acids. The study of R.-L. Heiniö *et al.*, 2008 shows that the characteristic intense flavour and aftertaste of the rye sourdough bread is related to vanillic and veratric acids, alkylresorcinol C23:0 and all lignans. Bitterness flavor is supposed to be the result of pinoresinol (a lignan) and syringic acid. The germ-like flavour comes from the sinapic and ferulic acids, alkylresorcinols except for alkylresorcinol C23:0 and syringaresinol, (Heiniö *et al.*, 2008).

According to Heiniö *et al.*, (2003), consumers evaluate that rye-like flavour was the most dominating sensory of the rye bread. Moreover, they perceive sourness and saltiness taste. All these flavors come from the flour, the additives, and obviously from the microbial flora and make the taste of rye and wheat bread different. Moreover, some flavors of the bread are given during baking thanks to the Maillard reaction and caramelization. Each flavour comes from a specific component which was degraded in a specific way. All the reactions happening in sourdough process are linked and give to the bread its aroma.

Although the favours and taste of sourdough bread is what sets it apart from regular yeast bread there are many other aspects that consumers feel are important when choosing bread and the nutritional benefits associated with sourdough bread is one of these aspects.

7.0 Nutritional benefits of Sourdough bread
By Shauna Cusack

The significant potential of sourdough fermentation to improve the nutritional properties of rye, oat and wheat products has gained very little attention, although the interest is at present increasing. Sourdough fermentation can modify healthiness of cereals in a number of ways:

- It can improve texture and palatability of whole grain, fibre-rich or gluten free products,
- Stabilise or increase levels of various bioactive compounds,
- Retard starch bioavailability (low glyceamic index products)
- Improve mineral bioavailability.

Sourdough bread is known as "the staff of life," because it enhances the entire immune system. The beneficial bacteria found in sourdough help control candida albicans. Candida Albicans is an opportunistic fungus that is the cause of many undesirable symptoms ranging from fatigue and weight gain, to joint pain and gas. When the Candida population starts getting out of control it weakens the intestinal wall, penetrating through into the bloodstream and spreading throughout the body causing serious damage to the immune system (Ryan, Ray, 2004).

In the process of making sourdough bread, during the rising time (called proofing), bran in the flour is broken down, releasing nutrients into the dough. In particular, the phytic acid (phytin) in grain needs to be 90% neutralized in order for the minerals, concentrated in the bran, to be absorbed by the human body. According to experiments done in Belgium, phytin can be neutralized by natural bacterial action and to a lesser extent, by baking. In naturally leavened bread, the combination eliminates all phytin, while in yeasted bread about 90% remains, (Sircus, 2010).

With sourdough bread, complex carbohydrates are broken down into more digestible simple sugars and protein is broken down into amino acids. Enzymes develop during proofing which are not lost in baking since the centre of the loaf remains at a lower temperature than the crust. It's the fermentation, partly from lactobacillus, that makes eating good quality bread an aid to digestion of all complex carbohydrate foods including other grains, beans, and vegetables. It helps restore the functioning of the digestive tract, resulting in proper assimilation and elimination.

Researchers reported that sourdough bread significantly lowered serum glucose and insulin responses and gave greater satisfaction than the other bread. "It is concluded that sourdough baking and other fermentation processes may improve the nutritional features of starch," the researchers concluded, (Bjarck, 1995).

Sourdough bread rates a 68 on the glycaemic index as opposed to the rating of 100 by other breads. It is known that glycemic response to bread is strongly affected by the presence of organic acids produced during sourdough fermentation. Foods that have low ratings on the glycaemic index are prominent in societies that tend to have lower incidence of diseases and unhealthy conditions that run rampant in our culture such as diabetes, (Bituh, 2011).

Sourdoughs are produced mainly from rye flour but also from wheat flour, (Ward, 1989). Rye flour contains high levels of proteins and soluble fibre which slows down the release of carbohydrates giving you the feeling of fullness for longer. It also has high amounts of iron, calcium, zinc and a large amount of B vitamins. The Finnish company Fazer have found rye to be a good source of prebiotics, making it a valuable food for cancer prevention, (Expert answer, 2010).

With sourdough processes the mouthfeel and palatability of wholemeal bread can be improved without removing any nutritionally important components. Sourdough baking processes also improve texture and flavour of bran-rich breads.

8.0 Wheat vs. Rye Sourdough Bread
By Stella Casserly

Sourdough rye bread is traditionally made in Finland and north-eastern Europe, whereas the most common bread made in European countries is made from a mixture of wheat and rye, (Hansen, 2005). The rye bread produced in western Finland is not as sour as the sourdough rye bread produced eastern Finland. The most common rye bread produced is small and flat with typical fibre content of approximately 10g/100g and approximately 2.5g per serving (25g). The production of rye bread is without the use of fat or milk, and in some specialities of bread often uses sugar, honey or syrup. Sourdough is used to improve the sensory properties of the bread and extend the shelf life if more that 20% of the flour is from rye, (Kulp, 2005).

During the production of sourdough rye bread the main function of using sourdough is to inactivate the α amylase activity, to achieve this a larger amount of sourdough is added to the dough if the activity of the enzymes are high in the flour, (Friberg, 2005). To prevent the degradation of starch sourdough is added to bread with a rye content of more than 20%, (Gallagher, 2004). At 52°C the starch in rye begins to swell and as a result the α amylase is able to break down the starch until it will be heat inactivated at 80°C. The optimum pH of rye α amylase is 5.5 and is completely inactivated in sourdough at pH below 4, (Friberg, 2005).

The proteins present in rye are different to the proteins present in wheat; they rye proteins do not form a gluten structure and protolytic activity in sourdough is caused by enzymes present in the flour, (Kent, 1994). One of the major differences between rye sourdough bread and wheat sourdough bread is that for rye sourdough bread it is essential to use rye sourdough to achieve the required baking performance of bakery products that contain rye flour however this does not apply in the use of wheat sourdough for bakery products. Wheat sourdough is incorporated into recipes primarily to enhance the flavour of the bakery products (panettone) or to emphasize a particular flavour profile (Sanfrancisco sourdough bread), (Friberg, 2005).

Another main difference is that rye flour can spontaneously generate rye sourdough over time whereas with wheat sourdough other ingredients such as yeast, salt, shortening and other additives are often added to the flour and water mixture when a wheat sourdough is produced, (Kulp, 2003). There is lower production of naturally occurring lactic acid bacteria in sieved wheat flour compared to rye flours. There is a lower nutrient content in the wheat dough compared to rye dough, (Arona, 2005).

Rye grains are more difficult to mill as they contain higher levels of arabinoxylans than wheat, (Friberg, 2005). Arabinoxylans are hygroscopic in nature, the rye flour absorbs ambient humidity and this results in the flour clumping together. As a consequence to this clumping together of flour it makes the sifiting of the flour more difficult for this reason rye flour is milled at a lower moisture content and requires more sifting surfaces than wheat, (Kent, 1994). If the protein level of rye exceeds 12% it becomes difficult to grind and has a lower extraction rate, (Arona, 2005).

There is also a difference during bread making between rye sourdough and wheat sourdough bread. Rye proteins are unable to form a gluten network compared to the bread quality of wheat sourdough

bread, (Hansen, 2005). Rye starch gelatinizes at a lower temperature compared to that of wheat starch and is therefore prone to enzymatic degradation during the oven phase than wheat starch. One of the main differences that can be observed between the two grains is that rye bread bakes at a lower volume to that of wheat but on the contrary rye bread has a longer shelf life and is richer in taste and aroma, (Friberg, 2005).

9.0 Gluten free sourdough
By Rachel Connon

Affecting about 1 percent of the population of the western world, celiac disease, an autoimmune disease, is the most common food induced enteropathy in humans caused by the ingestion of gluten proteins. Celiacs are intolerant to the gladin fraction of wheat, the prolamns of rye (secalns), barley (hordeins) and possibly oats (avidins). Celiacs suffer of self-perpetualing musocal inflammation characterises by the progressive loss of absorptive villi and hyperplasia of the crypts upon ingestion of gluten. The only treatment of celiac disease is the strict gluten-free diet which results in a mucosal recovery.

Gluten a protein in wheat, rye and barley is extracted from flour by kneading which agglomerates the gluten creating gluten strands and cross-links. It adds to the elasticity of the finished product, resulting in a baked product that is chewier in proportion to the length of kneading. The gluten allows the gas generated to be trapped and held in the dough structure, when it coagulates under the influence of heat during baking, it becomes the framework of the loaf, so that it becomes comparatively rigid and does not collapse. High gluten flour is particularly important in hearty breads such as sourdough.

Gluten has low resistance to deformation and maximum extensibility. The gliadin confers elasticity on the dough while acting as a binding agent to the tough glutenin, the glutenin confers stability and tenacity.
The production of high quality gluten free breads seems to be one of the biggest challenges faced by bakers and food scientist dealing with gluten free products due to the many roles of gluten in bread-making. Many studies found that gluten free bread was of low quality, exhibiting poor mouth feel and flavour, (Arendt *et al* 2002). Other problems found gluten free bread had a tendency to be can be quick staling and have a flat aroma.

Recent research investigated the possibility of using a sourdough starter culture as the basis for many gluten free breads had promising results due to the complex metabolic activity of the sourdough lactic acid bacteria it was suitable for Celiacs consumption. It was found that sourdough fermentation has a positive effect on the nutritional properties, taste, texture and shelf life of gluten free bread. A recent study carried out in the University of Bari found that the inclusion of sourdough made from rice, corn and amarantha may "enhance the recovery from intestinal inflammation of coeliac patients at the early stages of gluten free diet", (Calasso *et al,*. 2012). It was found to help reduce the pro-inflammatory markers such as nitric oxide in the intestines by over 30%.

The use of sourdough as a starter for gluten free bread has become a very promising because while enhancing the properties of the bread it could have potential benefits to sufferers of Celiacs disease.

10.0 Conclusion
By Sarah Morris

Sourdough bread is one of the most ancient forms of bread making, originating in Egypt its methods travelled across the world. In modern times San Francisco sourdough has become the most popular; however the ancient methods are in essence still the same. In this essay the importance of raw materials and the starter were discussed, the process was outlined and flavours and nutritional benefits talked about. It is apparent from this information that sourdough is very different compared to yeast bread, but not only this using different raw materials such as wheat flour or rye four can impact the sourdough bread greatly. Finally the importance of gluten in sourdough bread was outlined, and in today's society the use of sourdough starter for gluten free bread is looking promising.

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