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Yeast, its types and role in fermentation during bread making process-A Review

Akbar Ali, Aamir Shehzad, Moazzam Rafiq Khan, Muhammad Asim Shabbir, Muhammad Rizwan Amjid

National Institute of Food Science and Technology, University of Agriculture, Faisalabad Pakistan

Corresponding Author: aamir1326@yahoo.com

Abstract

The art of bread making goes back to very early stages of different historical eras. Bread is an important part of the human diet, but for many people, it is much more than just providing nutrients. Bread making can be a creative art—especially for the persons dealing with yeast breads. Many people enjoy creating beautiful and unique breads from yeast dough. The purpose of any leavener is to produce the gas that makes bread to rise during fermentation. Yeast does this by feeding on sugars in flour, and expelling carbon dioxide in the process. As the yeast feeds on sugar, it produces carbon dioxide. With no place to go but up, this gas slowly fills the balloon. A very similar process happens as bread rises. Carbon dioxide from yeast fills thousands of balloon-like bubbles in the dough. Once the bread has baked, this is what gives the loaf its airy texture. The present study will mainly deal with different types of yeast, its properties and different mathematical models to describe the dough behavior during fermentation.

Keywords: Yeasts, fermentation, dough behavior, mathematical modeling

Introduction

Yeasts are actually microbial eukaryotes which belong to ascomycetes that are good source of vitamin B and protein. Yeasts are plant-like unicellular fungi thriving on every living organism. Being living organism fungi require warmth, water, albumen or nitrogenous material and sugars to remain alive (The Artisan, The Yeast Treatise, 2002).

Yeasts are typically spherical, oval or cylindrical in shape and a single cell of *Sacharomyces. Cerevisiae* (a mold which ferments the sugar in cereal) is around 8 µm in diameter. Every cell has a double-layered wall, which is porous to certain substances and in this way food fabric is taken into the cell and metabolites leave it. Yeast is made up of many tiny, single-celled plants, which grow by budding and each bud breaking away from the parent cell and forming new buds. Though most yeast replicate only as single cells, under a number of circumstances some yeasts can figure out as filaments.

The conditions required for growth are warmth (optimum 25-30 °C), moisture and food (starch plus a small amount of sugar). Refrigeration slows down the growth so that yeast can be kept for a limited period of time. When the yeast is used, the conditions and the utensils should be kept lukewarm to obtain the best results. As soon as the yeast has been added to the dough or batter, the yeast begins to feed on the starch in the mixture, forming sugar, alcohol and carbon dioxide. The bubbles of CO_2 cause the dough to expand. The dough must be "kneaded" thoroughly to distribute the bubbles evenly and then left to rise again, usually to about double its original volume. If the mixture is left too long, acid produced by the oxidation of the alcohol results in taste sour of the product.

Yeasts thrive in habitats where sugars are present, such as fruits, flowers and bark of trees. However, saleable yeasts of today are fairly different from wild strains due to genetic treatment, allowing them to grow in inappropriate situations. The enzymes which are created by the yeast cells and act as natal catalysts in the fermentation process are maltase, invertase and zymase complex. Maltase has the aptitude to alter maltose, which is formed by starch degradation by alpha- and beta-amylases, to glucose and acts when the supply of simple sugars has been bushed. Invertase converts sucrose to glucose and fructose, while the doings of the zymase complex fallouts in the change of glucose, fructose and other simple sugars into carbon dioxide and ethanol. It is the carbon dioxide which raises the dough during fermentation (Madigan *et al.,* 2003).

Types of yeast

Baker's yeast is a commercial preparation consisting of dried cells of one or more strains of the fungus *Saccharomyces cerevisiae*. Bakers use yeast as a leavening agent in the rising of dough for baking. A secondary contribution of yeast to bread is flavouring and aroma. Bakers yeast is a high volume, low value product, with 1574 x 106 kg being produced per annum on a global scale (O'Shea, 2005)

Baker's yeast is marketed in two ways, either as compressed cakes or as a dry powder, however there is also a saleable intermediate of the process known as 'cream yeast'. Process considerations include media formulation (which has to be cost effective), and the limited respiratory capacity of yeast, which inhibits the production of biomass in favour of ethanol production. The fermentation of bakers yeast is strongly directed towards maximum biomass production, no byproducts

such as ethanol are desired and so the fermentations are sectioned to obtain this maximum biomass (Van Hoek *et al.,* 2003).

Now a days, baker's yeast is a product of biochemical, microbiological, technical knowledge and experience. Biochemistry has led to an insight into the fermentation process; microbiology has made it possible to breed new and better strains of yeast and to develop better techniques for sterilization and disinfection. Advanced technologies have led to the large scale production of yeast with a high degree of automation and process control, giving commercial yeast of consistent quality and activity at an economic price. By feeding on sugars from the starch in flour, yeast produces carbon dioxide. This gas expands the gluten proteins in the flour and causes the dough to rise, this process of bread making being the most commonly associated with yeast. Scientists now cultivate strains of bakers yeast for their ability to make dough rise and produce loaves of good height, texture and flavour.

Cream yeast is not typically termed a 'bakers yeast product' but is relevant as it represents a major step in the process and is a marketable product itself. At the end of the fermentation, the fermentor/yeast broth is concentrated using a series of combined centrifugation and washing steps, into a yeast cream with a solids concentration of approximately 20 %. The yeast is then cooled to approximately 4 °C, an ideal temperature to restrict the growth of any contaminating mesophilic microorganisms. The cooled yeast cream is stored in a stainless steel cream tank, which is insulated and equipped with agitators and cooling pipes (Kristiansen, 1994). Effectively preventing heat exchange with the surrounding atmosphere, keeping the cream at 4 °C. Following storage either of two pathways can be followed. The first involves the preparation for sale of the cream yeast itself. Cream yeast is basically the liquid product and can therefore be transferred into sterile tanks/containers and distributed to bakeries, where it is used to produce yeast based products. The advantage of cream yeast is that it excludes any human handling thus reducing the risk of contamination by handling, however due to its high (water) volume, transport costs can be expensive. For this reason, distribution is generally confined to a particular area (Lallemand, 2001).

Granular yeast, also known as instant dried yeast, is a form of compressed yeast. Stored cream/liquid yeast is passed through a filter, usually a filter press or rotary vacuum filter, which removes water increasing its solids content to approximately 30 %. Salt may also be added to the cream yeast prior to filtration to aid the removal of water. The filtered yeast is then dried using fluid-bed dryers. As the yeast is dry it generally does not require refrigeration as the low water content reduces the risk of microbial contamination. Emulsifiers and oils can be added at this point to texturize the yeast and aid the cutting process. As the name implies, granular yeast is crumbled into granules, the granulation process being carried out by a granulator. Granular broths are typically used to make restoring drinks to serve in a cup; the practicality of granular products coming both from their instantly soluble nature and the fact that they are easily measured (Bauer, 2005).

The filtered and dried yeast can alternatively be used to make cake yeast. Cake yeast is another form of compressed yeast and can be categorized as active dry yeast. It differs from granular yeast in that rather than granulation, the dried yeast is extruded or cut into blocks/cakes. Similar to granular yeast cake yeast also contains about 30 % solids (70 % water). The composition of solids may vary depending on the growth rate of the yeast as lower growth rates give lower protein, lower activity, higher carbohydrate, and higher stability (Lallemand, 2001)

Properties of yeast

Preservatives are commonly used in breads because economic losses from bread spoilage caused by bacteria or by moulds are substantial. Ropy spoilage is caused mainly by *Bacillus subtilis* and *Bacillus licheniformis*, the spores of which contaminate raw materials such as flour, bread improvers, yeast, etc., and survive baking temperatures (Rosenkvist and Hansen, 1995).

Ropy spoilage in bread is first detected by an odour similar to that of pineapple. Later, the crumb becomes discoloured, soft and sticky to the touch, which makes the bread inedible. The deterioration of bread texture is due to slime being formed as a result of the combined effect of the proteolytic and amylolytic enzymes produced by some bacillus strains that results in slime formation (Viljoen and von Holy, 1997; Sorokulova *et al.,* 2003). The full extent of losses caused by ropy spoilage of bread is difficult to quantify, because the condition is often misidentified as sour or rotten spoilage caused by failed dough leavening or an insufficient bake. Consumption of ropy bread may cause illness if bacteria are present at ≥108 cfu/g (Kramer and Gilbert, 1989; Rosenkvist and Hansen, 1995). Ropiness can develop very rapidly under warm and humid conditions, so it is a common problem in the warm climates of Mediterranean countries, Africa and Australia (Voysey and Hammond, 1993). Bacillus spore numbers can be controlled by ensuring raw material quality, good sanitation and cooling of production and storage environments (Viljoen and von Holy, 1997). Spore germination and growth in bread can be inhibited by chemical preservatives such as propionic and acetic acids, although the current trend is to reduce the levels of these substances (Pattison *et al.,* 2004; Marin *et al.,* 2002). Acetic acid adversely affects the organoleptic quality of baked products, while propionic acid has been reported to cause irritability, restlessness, inattention and sleep disturbance in some children (Dengate and Ruben,

2002; Spicher, 1983). Alternative antimicrobial systems to prevent bread spoilage are therefore required.

The yeast used for bread manufacturing is *Saccharomyces cerevisiae*, often referred to as simply baker's yeast. It converts the fermentable sugars present in the dough into carbon dioxide and ethanol as the main products. The fermentation intensity depends on the form of the yeast and the availability of fermentable sugars in the flour, including maltose produced by starch hydrolysis (Hutkins, 2006).

During the bread-making process, baker's yeast (mostly strains of *Saccharomyces cerevisiae*) is uncovered to many environmental stresses such as air-drying, freeze–thaw, and high-sucrose concentrations (Attfield, 1997). Yeast cells worn for bread making must acclimatize to different sucrose concentrations during dough-fermentation processes (Tanaka *et al.,* 2006). In exacting, sweet dough (high-sugar dough) contains up to roughly 30 % sucrose per weight of flour. Such high-sucrose concentrations apply harsh osmotic stress that badly damages cellular mechanism (Verstrepen *et al.,* 2004) and hold back the optimal fermentation aptitude of yeast. To evade lethal injury, baker's yeast cells want to get osmotolerance, but the progress of osmotolerant baker's yeast strains will require knowledge of the molecular mechanism concerned in high-sucrose stress lenience, for example, by the introduction of stress proteins, the buildup of stress protectants, and the variations in membrane composition (Shima & Takagi, 2009).

When elevated osmotic pressure is felt, *S. cerevisiae* cells collect glycerol and trehalose (Cronwright *et al.,* 2002; De Virgilio *et al.,* 1994; Hino *et al.,* 1990; Hirasawa *et al.,* 2006; Shima *et al.,* 1999). Microarray examination and genome-wide screening using a removal strain group exposed that the metabolism of glycerol and trehalose, both of which are recognized as osmoprotectants, is significant for high-sucrose stress tolerance (Ando *et al.,* 2006; Tanaka-Tsuno *et al.,* 2007). In reply to osmotic stress, proline is accumulated in many plant and bacterial
cells as an osmoprotectant (Csonka, 1981; Verbruggen & Hermans, 2008). During a variety of stresses, yeast cells encourage glycerol or trehalose production, but the intracellular proline level is not augmented under a range of stress circumstances (Kaino & Takagi, 2008). Proline has many functions in vitro, such as protein and membrane stabilization, decreasing the Tm of DNA, and scavenging of hasty oxygen species (ROS), but the mechanisms of these functions in vivo are not well understood (Takagi, 2008). *Sacharomyces cerevisiae* cells that collect proline, and the engineered strains effectively indicated improved lenience to many stresses, counting freezing, desiccation, oxidation and ethanol (Matsuura & Takagi, 2005; Morita *et al.,* 2002; Takagi *et al.,* 1997; Takagi *et al.,* 2000; Takagi *et al.,* 2005; Terao *et al.,* 2003). With respect to high osmotic pressure, it was found that the proline oxidase-deficient strain, which had a considerably elevated proline level, was obviously more osmotolerant than were other strains in the existence of 1 M NaCl (Takagi *et al.,* 1997). Recently, it was found that proline accumulating baker's yeast retained higher-level fermentation aptitude in the frozen dough than that of the wild-type strain (Kaino *et al.,* 2008). Based on these results, it is concluded that it is possible that proline collection confers tolerance to high-sucrose stress on baker's yeast. For the application of recombinant yeasts for marketable use, self-cloning yeast that has no foreign genes or DNA sequences apart from yeast DNA might be more satisfactory for consumers than a genetically modified yeast.

There is no doubt that folate (vitamin B9) has a vital role in primary cell processes, such as nucleic acid and amino acid biosynthesis. Inadequate folate intake may lead to the typical folate insufficiency disease megaloblastic anaemia (Wickramasinghe, 2006) and greater risks for neural tube defects (Berry *et al.,* 1999; Wald *et al.,* 1996) as well as other malformations (Lucock, 2000). In addition, the useful role of folate for more than a few other diseases such as cardiovascular diseases (Brouwer *et al.,* 1999), Alzheimer's disease (Seshadri *et al.,* 2002) and some forms of cancer (Choi and Mason, 2000) is under careful examination.

Humans are, in contrast to yeasts and plants, auxotrophic for this vitamin and must therefore satisfy their needs by the diet. For a large portion of humankind though, it is very tough to sustain the daily intake on sufficient levels. One striking idea to boost folate intake is to employ biotechnology to improve the concentration of ordinary folates in food-as opposed to supplement food by using man-made folates or use supplementation by tablets.

Baker's yeast, *Saccharomyces cerevisiae*, has been found to generally contain a relatively high amount of folate per weight (Witthöft *et al.,* 1999). Seyoum and Selhub (1998) described a total folate content of 24.5 µg/g of dry matter of yeast while Patring and Jastrebova (2007) reported 35.2 µg/g. Folates from yeast obviously add to the finishing folate content in yeast fermented foodstuffs, such as bread (Kariluoto *et al.,* 2004; Gujska and Majewska, 2005) and kefir (Drewek and Czarnocka-Roczniakowa, 1986). In wheat bread folate levels were improved 2.5 times when using yeast, in place of baking powder, as leavening agent (Kariluoto *et al.,* 2004).

Experimental structure on fermentation

Henry and Saini (1989) described that the most significant carbohydrates from flour influencing the loaf volume are glucose, fructose and sucrose. The arrangement in which these different carbohydrates are fermented by *Saccharomyces cerevisiae* is not at random, but rather is based on a specific pecking order, glucose being the preferred sugar. It is considered that glucose decreases the uptake of fructose because both sugars are

imported by the same carriers, which have a greater empathy for glucose than for fructose (Verstrepen *et al.,* 2004).

Of the above mentioned carbohydrates, sucrose is changed almost right away to glucose and fructose, due to the effective invertase of yeast (Sahlsrtom *et al.,* 2003). When the concentration of glucose and fructose is elevated enough, the maltose concentration in dough is also mounted due to amylase, a starch debasing enzyme in flour, which is continuously generating new glucose and maltose in flour starch. When glucose and fructose are ended, the maltose concentration begins to lessen, making difficult for yeast cells to hydrolyze since they do not have the essential enzymatic tools in time, working methods and techniques such as thin layer chromatography (Sasano *et al.,* 2012).

Mathematical modeling of dough behavior during yeast fermentation

Bread making is fundamentally a temperature-dependent two step progression, consisting of fermentation, in which CO_2 production linked with yeast activity is manifested in porous dough structure with the development of dough volume during baking where yeast activity is ended and the bread structure is finalized. During baking, the inside temperature reaches 100 °C and the volume fraction of bread reaches a final value between 0.8 and 0.9 (Shehzad *et al.,* 2010; Shehzad *et al.,* 2011), while gluten cross-links and starch granules are disrupted (Franci and Igore, 2011).

The concluding bread structure depends on dough ingredients, yeast activity, fermentation temperature and gas bubble formation. So far, the bread making has been studied at different scales by various imaging modalities, such as flatbed scanning and conventional photography (Lassoued *et al.,* 2007), as well as by more highly developed high-resolution techniques, e.g., scanning electron microscopy (Hayman *et al.,* 1998), X-ray computed tomography (Babin *et al.,* 2006; Turbin-Orger *et al.,* 2012) and magnetic resonance imaging (MRI). The effect of yeast during fermentation of wheat flour dough was also studied at macro scale (Shehzad *et al.,* 2010). Among all these techniques, both at macro and micro scales, MRI has numerous advantages due to its non invasiveness, precise moisture content determination and a comparatively high spatial resolution. For example, Ishida *et al.,* (2001) employed MRI to analyze differences in architecture between breads made from fresh and frozen dough. To improve an image contrast and to shorten relaxation times, they soaked bread samples in acetone with added paramagnetic substances prior to imaging.

One of the first MRI experiments with dynamic imaging of baking was done by (Hong *et al.,* 1996) who introduced a specially designed MRI oven, constructed from nonmagnetic materials. This was used to learn cookie baking in a low field MRI scanner (0.6 T). Another similar experiment was done by (Wagner *et al.,* 2008) who used a spacious MRI oven well-matched with a low-field MRI scanner (0.2 T) to monitor bread loaf fermentation and baking. (De Guio *et al.,* 2009) used vulnerability effects in low-field MRI (0.2 T) to study the growth of pores in different dough (yeasted and non-yeasted) during fermentation. Results of the study showed that pores have a Gaussian-like size (radii) distribution with a gradual increasing average size that is associated with the dough rise during fermentation.

All the above-presented low-field MRI experiments have a good temporal resolution and image quality; however, they are lacking in spatial resolution. The resolution problem can be overcome by the use of high-field MRI scanners that permit magnetic resonance microscopy (MRM) experiments. One such experiment was done by (van Duynhoven *et al.,* 2003) who dynamically imaged dough fermentation using a 4.7-T MRI scanner with a spatial resolution of 0.27×0.27×3 mm and a temporal resolution of 2 min. Advanced magnetic field of 9.4 T was employed in experiments done by (Bonny *et al.,* 2004) who imaged the same process at a resolution of $0.12\times0.12\times0.5$ mm^3, but with a lower temporal resolution of 8.5 min. A similar study was completed also using 3D MR imaging with an isotropic resolution below 100 μm (Takano *et al.,* 2002).

All these high-field MRI studies were constrained by constant sample volume changes, so that the optimal imaging parameters were selected as the best cooperate between the spatial resolution and the temporal resolution, i.e., too low a temporal resolution would result in motional blurring. Image processing routines are a powerful device in analysis of dough texture properties. Standard image processing techniques (thresholding, particle counting, area and volume measurements) are inadequate to extort all available information on dough fermentation and baking (Ishida *et al.,* 2001). Therefore, advanced image processing techniques, as for example mathematical morphology routines (dilation, erosion, closing, opening, etc.), are often used in addition to the standard ones (Rouille *et al.,* 2005).

Dough is a multiphase and multi-component system largely composed of proteins, lipids, carbohydrates, water and air. The dough ingredients, as well as the processing conditions, determine the macroscopic structure of baked foodstuffs which, in turn, is responsible for their appearance, texture, taste and stability. To build up this structure, the ingredients are mixed and kneaded, the dough leavened and baked. Enormous structural changes take place during the bread making methods (Autio and Laurikainen, 1997). During mixing, the ingredients are transformed into a visco-elastic material as a result of the formation of a three-dimensional protein network, in which starch granules are consistently detached. During kneading, air bubbles are built-in in the dough and they are assumed to be the early nuclei of the gas bubble, which will build up during the

succeeding stages. During leavening, the metabolism of yeasts chemically transforms assimilable carbohydrates into carbon dioxide and ethyl alcohol as the principal finished products. As a related amount of alcohol forms, which is water-miscible, it influences the colloidal nature of the wheat proteins and changes the interfacial tension within the dough. In addition, carbon dioxide, which partly dissolves in the aqueous phase of the dough, migrates toward the initial nuclei of the air bubbles formed during kneading causing their growth. The growth of gas cells depends on the cell size and the dough composition. Certain ingredients are known to exert a stabilizing influence and retard coalescence (Gan, Ellis, and Schofield, 1995). It is important to distinguish between gas production and gas retention in fermented doughs (Cauvain, 2001). The first factor is controlled by the yeast performance and the last one depends on the bubble characteristics. The desirable loaf volume of yeast-fermented products is achieved only if the dough provides a favorable environment for yeast growth and gas generation and, at the same time, possesses a gluten matrix capable of maximum gas retention (Sahlstro¨m, Park, and Shelton, 2004). The latter attribute is most conveniently determined by measuring the volume increase of fermenting dough, whereas gas production can be estimated by any of the several available procedures such as the oven rise recorder (Marek and Bushuk, 1967), alveograph method (Approved Method 54-40, AACC, 2000) and pressure meter methods (Bailey, 1939; Malloch, 1939). Yeast-fermented doughs are difficult to study, because they are very complex, and the dimensions and physical properties of the dough change with time (Bloksma, 1990; Szczesniak, 1988). Furthermore invasive, continuous measurements on dough are generally not adequate as they may provoke dough collapse. The choice of the most appropriate analytical procedure is thus crucial for the full comprehension of the underlying mechanisms of leavening. From a structural point of view bread dough is an elastic foam and leavening is a process very similar to the expansion of a pseudoplastic foam, in which initial germs (yeast) are quasi-homogeneously distributed into the dough volume. Little is known about the physical processes governing foam formation. Some of the main issues are the lack of robust test methods to quantify their behavior, concerns about the reliability of the data, variability in the material properties and the need to relate structure to behavior (Lim and Barigou, 2004). There is a real need for robust quantitative methods for characterizing the structure of these materials, so that intrinsic relationships between structure and properties can be developed. Image analysis is potentially a non-intrusive, objective method for measurement and comparison of the structure of food foams that will allow quality control and process optimization (Cilliers and Sadr-kazemi, 1999). The most apparent physical change related to the development of fermentation in the dough is the increase in its volume (Pyler, 1988). Although, an extensive the literature exists dealing with the control of the leavening process (De Cindio and Correra, 1995; Dixon and Kell, 1989; Pinter, 1988) and mathematical models and equations for expression of microbial growth in food (Fan, Yingying, Qian, and Gu, 2004; Fujikawa, Kai, and Morozumi, 2004; Vadasz, Vadasz, Abashar, and Gupthar, 2001), the description of such a process will always be a rough simplification of reality, since detailed picture of the various biological and physical phenomena responsible for bubbles growth during the leavening process are still difficult to model. Fermentation involves biochemical, rheological and thermodynamic phenomena, which are nonlinear distributed-parameter processes. Growth curves are generally of sigmoid shape with a first stage in which the specific growth rate starting from zero slowly increases for a period of time known as lag time. After this period, a fast increasing growth rate phase follows in which a maximum rate value is achieved at the inflection point (Shehzad *et al.,* 2010). Finally, a plateau is reached in a final phase in which the rate decreases and eventually became zero. These kinds of sigmoid curves can be fitted by different mathematical functions, such as monomolecular, von Bertalanffy, Gompertz and logistic (McCallum and Dixon, 1990). A major development in the analysis of growth curves has been the generalization of these sigmoid growths to a single function, i.e. the Gompertz function (Zwietering, Jongenburger, Rombouts, and van't Riet, 1990). Since that, the Gompertz ($y = \ln x(t)$) model has become the standard growth model in predictive microbiology for modeling growth of pathogens and spoilage bacteria in food (Whiting and Buchanan, 1994). The effect of yeast on dough volume during fermentation was modeled by different researchers using Gompertz equation (Romano *et al.,* 2007; Shehzad *et al.,* 2010; Kansou *et al.,* 2012), thus providing very useful information about various aspects of fermentation, especially evolution of dough volume during yeast fermentation.

Conclusion

Yeast plays a vital role in dough expansion during fermentation due to CO_2 production along with development of flavor and alcohol synthesis. Although various studies indicated its importance during the fermentation process but its role was not thoroughly discussed which needed to be addressed. In its natural, fresh form, yeast is considered to act as catalyst for breakdown of sugars due to fermentation process. Different types and forms of yeast develop different flavors and may give rise to dough volume depending upon amount of gas produced within the dough as a result of yeast action on sugars. Although, dough behavior during fermentation can be presented in form of sigmoidal curves using different mathematical models and has been studied by various researchers but the effect of different types and forms of yeasts on dough behavior

during fermentation needs further study and can elucidate useful results for breadmaking industry.

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