Baker's yeast production and applications

Introduction

Humans have consumed cereals since prehistoric times. In Mesopotamia, baked pastes of ground grain were consumed, while, in Egypt, leavened bread was prepared. For thousands of years, humans were unaware of the existence of yeasts but were able to use them not only for breadmaking but also for brewing. The fundamental role of yeasts and bacteria in fermentation processes was only discovered in the last century by Pasteur. Soon after this, Hansen established the use of pure cultures for brewing and baking. Until that time, bakers used spent brewer's yeast for leavening, or seeded the fresh dough with a small part of already leavened dough. The commercial production of yeast for baking purposes started after about 1850, and since then, yeast technology has grown into a highly productive and economic industry. 'Yeast' in this article refers solely to the species *Saccharomyces cerevisiae*.

The Organism

Baker's yeast is a biotype of *S. cerevisiae* that can metabolize sugars both aerobically, producing the end products carbon dioxide and water, and anaerobically, producing ethanol and carbon dioxide. Thus, baker's yeast can be propagated in large quantities under aerobic conditions, and the cell mass added to dough can produce carbon dioxide under various conditions to leaven bakery products. These are the fundamental properties of baker's yeast that render it indispensable to the production of bread. Through this century-old application, many specific requirements have been imposed by the producer and the user, and strains have been selected with improved properties to meet these requirements. The strains used today are able to reproduce rapidly under strong aeration and limited nutrient supply. The yeast cells show remarkable tolerance to various storage conditions, and survive drying. Baker's yeast possesses strong fermentative activity and flavor development in various conditions of processing.

Production

There are at least four major steps in the manufacture of baker's yeast: preparation, fermentation, separation, and packaging (Figure 1).

Preparation

The manufacture of baker's yeast starts in two separate areas: in the laboratory with the propagation of a pure yeast culture, and in the factory with the preparation of the fermenters and the nutrient medium.

In the laboratory, where pure stock cultures are maintained, a small flask of sterile fresh culture is prepared after one or more subcultivations. This sample is then inoculated into the first pure culture tank. Two or three tanks of increasing capacity from 50 to 400 l may be applied. The yeast produced in an earlier stage is used to seed the next stage, while transfer is made under sterile conditions. In these early stages of propagation, the main concern is to maintain purity.

The pure culture fermenters are fed with sterile molasses medium supplemented with the necessary growth factors, but aeration with filtered air is not at full capacity in the first batch fermentation.

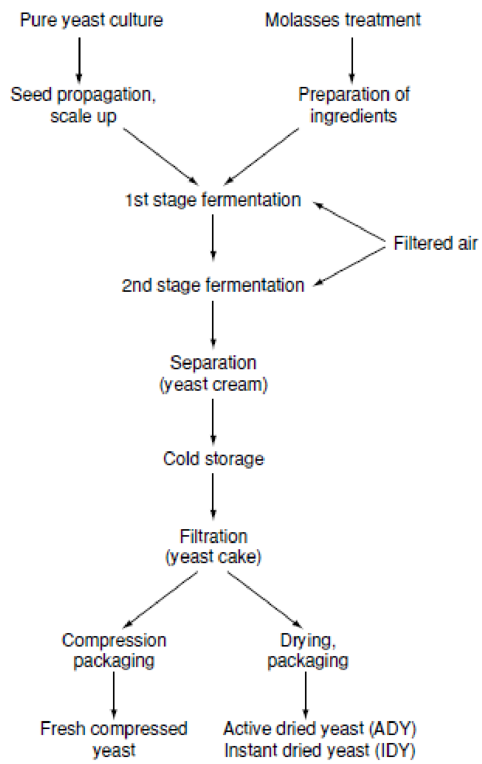

Figure 1. Flow chart for the production of baker's yeast.

Before the First World War, grain mash was used for the commercial propagation of yeast. During the war, shortages of grain led to its replacement by molasses, a relatively cheap byproduct of cane and beet-sugar production. Since then, molasses has become the traditional source of carbon and energy for yeast growth. It is usually fortified with a source of nitrogen, minerals and growth factors. Nitrogen is added in the form of ammonia, its salts, or urea; phosphorus is supplied in the form of phosphoric acid or ammonium phosphate. Depending on the composition of the raw molasses, certain growth factors, most frequently biotin, are also added to the wort. The concentrated molasses is diluted, purified, supplemented with other nutrients, and sterilized before use.

Fermentation

Baker's yeast is usually produced in a multiple-stage process. During scale-up, strong aeration and incremental feeding are introduced. Full-scale fermentation is conducted in large (100 m^3 or larger) tanks. There is a great variation in the size and shape of fermenters. However, in their design, an important requirement is to insure maximum aeration, because it is the oxygen transfer that is usually the rate limiting factor in yeast propagation. Mechanical and sparger aeration systems are generally used. During the aerobic growth of yeast, a considerable amount of heat is liberated, and an efficient cooling system is also an integral part of the fermenter. The strict demands for hygiene determine the overall construction of the fermenter and the materials used therein. Facilities for cleaning in place are always integrated.

After cleaning and disinfection, the fermenter is fed with water, in which the pure seed yeast is suspended, then mixed with wort, and the propagation starts with vigorous aeration. Baker's yeast 'fermentation' is a typical fed-batch process in that, after commencing the propagation, nutrients are fed incrementally, maintaining at all times a very low sugar concentration at full aeration. The protocols for nutrient feed rate, temperature, pH, and aeration are specifically set up and strictly controlled to optimize yield, productivity, and product quality. Special attention is paid to prevent underaeration, which leads to excessive alcohol formation and a decrease in productivity. Instrumental process control and automation are necessary to produce baker's yeast economically. Adequate sensors and computer applications now make it possible to control the most sophisticated fermenter systems. Baker's yeast producers, however, have to consider the baking quality (stability and activity) of the product, which can be attained at the cost of productivity. As a satisfactory compromise, at the final stage of fermentation, nutrient feeding is stopped, and aeration is continued for about an hour. During this ripening period, the properties of baker's yeast are improved. Nitrogen starvation increases stability, but fermentative activity decreases. At the end of a typical fermentation, the yeast solid content may vary between 3 and 8%, which means a yield of about 20 000–30 000 kg of fresh yeast in one batch propagation at 28–30 °C for 12–18 h.

Efforts to introduce continuous fermentations on a commercial scale have remained unsuccessful. Although continuous systems can be maintained at a maximum yield, a good product quality can be achieved only with propagation regimes that do not easily lend themselves to continuous culture. Moreover, the problem of preventing contamination raises the cost and makes the process economically unfeasible.

Separation and Filtration

At the end of each fed-batch propagation period, the yeast cells are recovered from the spent medium by centrifugation. Water wash is applied between two passages through centrifugal separators. A yeast cream is obtained with 18–20% dry weight, which can be stored in agitated tanks at 2–4 °C for a few days without any loss of quality.

The yeast cream is further concentrated by filtration on rotary vacuum filters or filter presses. Filtration yields a yeast cake of about 27–30% dry matter content.

Packaging

After filtration, the yeast cake is mixed with oils, emulsifiers, and a small amount of water, then compressed and extruded into blocks, or granulated for bulk distribution. The oil and emulsifiers improve product appearance and aid the formation of blocks (extrusion, cutting).

The Product

Compressed Yeast

This is the form of baker's yeast produced by the process outlined above. Compressed yeast is the traditional form of baker's yeast, which is available to wholesale bakers in 0.5–2.0-kg blocks, while smaller (10–50 g) blocks are prepared for households. Compressed yeast wrapped with waxed paper and stored at 4 °C keeps for a few weeks. A granulated pressed cake form of the same product packed in 10–20-kg bags can also be prepared for large-scale bakeries.

Compressed yeast cells are alive. They use their reserve carbohydrates (glycogen, trehalose) for energy to survive. Storage under refrigeration retards metabolism, and wrapping inhibits drying out. Under improper storage conditions, deterioration processes (autofermentation, autolysis) may start, resulting in heat build-up and loss of yeast activity.

Dried Yeast

In a dried form, baker's yeast possesses a longer shelflife than compressed yeast. Dried yeast retains stability even when stored at room temperature. It offers benefits by reducing the cost of refrigeration, transport and storage, but drying increases the expenses of the manufacturer. The disadvantage for the user arising from the lower activity of heat stressed cells is compensated by the ready availability of dried yeast. In all, there is an increasing preference and a growing share in the market for dried yeast. There are two forms of dried yeast. The first, introduced about 50 years ago, active dried yeast (ADY) needs to be rehydrated in warm water before use. Developed only in the last decade, instant dried yeast (IDY) does not require rehydration and can be mixed directly with flour in making dough. The early procedures of yeast propagation for drying are basically similar to those of the traditional baker's yeast fermentation. However, specific yeast strains selected to withstand drying stresses are used, and the final stages of propagation are set in order to increase yeast resistance to drying. The feeding schedule and maturation period are controlled to produce yeast with lower protein but higher trehalose and lipid contents.

Preparation of the yeast for drying begins with extrusion of the compressed yeast cake into slender strands (1–3-mm diameter) that are cut into short pieces. These particles are dried in a hot air current; the early procedure of tunnel drying has been mostly replaced by tumble or rotating driers and, increasingly, by fluidized bed driers. Only the latter are suitable for the production of IDY. Airlift driers employ a blast of hot air at a velocity sufficient to suspend the yeast particles in a fluidized bed. Air temperatures of 160 °C can be used for quick drying but, after loss of the free cell water content (at about 35% moisture), temperatures should not exceed 40 °C in order to minimize cell-membrane damage and reduction of enzyme activity. Cells are rapidly killed at temperatures exceeding 50 _C.

Themoisture content of ADY ranges from6 to 8%, whereas that of IDY is only between 4 and 6%. ADY possesses only one-third to one-half of the leavening activity of fresh compressed yeast (Table 1). The instant drying procedure allows the production of yeast with a leavening activity comparable with that of compressed yeast.

Table 1 Main characteristics of commercial baker's yeast products

Product	Form	Method of drying	Dry (%)	Protein (%)[a]	Gas production (%)[b]
Compressed yeast	Blocks or granules	None	30	52	100
Active dried yeast	Irregular spheres	Drum	94	40	45
	Irregular particles	Belt	94	40	40
Instant dried yeast	Short rods	Fluidized bed	96	48	80

[a]Nitrogen × 6.5.
[b]Related to the activity of compressed yeast.

ADY can be stored without refrigeration. During storage, ADY loses its activity by 1% per month if packed under vacuum or under nitrogen. On storage in air at ambient temperature, the loss of activity is faster. In order to restore activity, rehydration of ADY should be carried out by adding warm (40 °C) water to the yeast in a 4:1 ratio. During rehydration, 20–30% leakage of intracellular materials occurs, which leads to a loss of fermentation activity. A further disadvantage of this leaching is that it releases reducing substances, such as glutathione, which may cause slackening in the dough.

IDY particles are highly porous and easy to rehydrate. This allows immediate use without prior rehydration. However, air may also access the cells, resulting in rapid oxidation and loss of activity. Hence, IDY must be packed under vacuum or in a nitrogen atmosphere, and must be used within a few days after opening the package.

Addition of a variety of agents to the yeast cake prior to drying can improve activity and stability of dried yeast. Emulsifiers (e.g., 1% sorbitan esters) facilitate rehydration of IDY, and antioxidants (e.g., 0.1% butylated hydroxyanisole) increase the stability of ADY.

Applications

The application of baker's yeast is indispensable to the production of leavened baked products, such as breads, rolls, pastries, doughnuts, etc. Recipes and technologies for these products vary world-wide, but the essence of the process is the same, in that after mixing flour, water, yeast, salt, and optional ingredients, the dough undergoes panary fermentation before baking. The primary role of baker's yeast in the baking industry will be illustrated using as an example the predominant product, white bread.

Breadmaking

Conventional breadmaking technology involves sponge dough. This dough comprises about two-thirds of the total flour mixed with water, salt, and yeast, and is left for a fermentation period of 4–5h. The sponge is then added to the balance of flour, water, and all remaining ingredients and thoroughly mixed mechanically until it is transformed into a smooth dough. The characteristic rheological properties of the dough are due to the structure of gluten, a cross-linked network formed from wheat proteins and lipids. This allows the elasticity of dough to retain gas evolved by yeast and thus to leaven.

The dough undergoes a series of mechanical operations (divided into pieces, rounded, and moulded) while being allowed to rest between these procedures for short periods. During these proofing periods, fermentation proceeds, and leavening continues. After the final proof, loaves are placed into a hot oven for baking. Within the loaf, gas expands, steam and alcohol evaporate to form holes in the coagulated matrix of gluten, and the characteristic structure of the crumb sets. While the temperature in the center of the loaf remains below 100 °C, the surface reaches 140 °C, to form a hard, brown colored crust. The baked bread is left to cool before the finishing operations (slicing, wrapping) and distribution.

The conventional sponge dough technology requires about 8 h to finish, and several alternative methods have been developed to shorten this period (Table 2). In the straight dough method, all the ingredients are mixed at the start, and one bulk fermentation period of 2–4 h is allowed for leavening. In the short-time dough process, only 15–30 min are allotted for the dough to rest, and intense mechanical working brings about the structure of the dough. Time is also saved by the continuous mix processes, in which a ferment or brew is first prepared from yeast with little or no flour (liquid ferment), and after about 2 h of fermentation, the dough is mechanically developed in a continuous mixer. Bulk fermentation of the dough can be replaced by intense mechanical working and/or the addition of chemical improvers in other process variants. Improvements in equipment design have brought about savings in labor, better control and automation, effective sanitation, and greater processing flexibility of breadmaking technology.

Table 2. Schematic comparison of breadmaking processes

Time (h)	*Sponge dough*	*Straight dough*	*Continuous mix*	*Short-time dough*
7	Mixing			
6				
5	Sponge	Mixing		
4		Dough	Liquid ferment	
3	Mixing	Dividing Rounding		
	Dough			
2	Dividing Rounding 1st proof Molding	1st proof	Mixing Developing Dividing Rounding	High-speed mixing Dividing Rounding 1st proof
1	2nd proof	2nd proof	Mixing Proofing	Molding 2nd proof
0	Baking	Baking	Baking	Baking

Role of Yeast

Yeast plays three major functions in the dough: leavening, maturing, and flavor development.

Leavening: The increase of dough volume is due to the production of carbon dioxide during yeast fermentation of the carbohydrates available in the flour. Dry flour contains approximately 1–8% fermentable sugars (glucose, fructose, sucrose), whereas maltose is produced from starch granules by wheat amylases after wetting the flour.

Yeast has to adapt to the mostly anaerobic environment in the dough as well as to the fermentation of maltose after depletion of available free sugars. Yeast also has to tolerate a certain degree of osmotic pressure exerted by salt (and sugars, if added). The concentration of solutes is higher at the first stage of dough preparation when only half of the regular water is added. In certain formulae, sucrose or high-fructose syrup is used to sweeten the dough. Increasing the osmotic stress not only reduces the fermentation rate but also induces glycerol production.

Maturation: To some extent, both yeast itself and its fermentation activity play important roles in developing the texture of the dough, called maturation. This involves complex changes, including the mechanical forces of mixing leading to gluten formation. Carbon dioxide developed during yeast fermentation would not produce gas cells without the ability of viscoelastic gluten films to retain the gas. In fact, it is the air bubbles preformed in the dough during mixing into which the carbon dioxide diffuses. The rheological properties of the dough are influenced by the fermentation products (ethanol, pH decrease) in a way not yet clearly understood. Reduced compound (e.g., glutathione) liberated from yeast cells may split the disulfide bonds between gluten molecules, leading to the cleavage of the gluten structure.

Taste and Flavor: The characteristic and appealing bread aroma would not develop without yeast. It is difficult to characterize the complex nature of bread aroma and to determine the precise role of yeast fermentation in its development. More than 200 volatile compounds have been identified by gas chromatography, and many of these organic esters and acids, alcohols, and carbonyl compounds are formed as byproducts of yeast fermentation. Other compounds, such as amino acids, originate from the yeast cells. In addition to fermentation, bread aroma is determined by the process of baking, which leads to crust browning. This is a Maillard-type reaction, and its extent is influenced by the fermentation products of yeast and its cell constituents.

Sour Dough

Before baker's yeast was available commercially, part of leavened dough was added as an inoculum to the fresh dough. Acidification normally took place in this old dough, hence the name: sour dough. In recent years, consumption of sour-dough breads has greatly increased. The use of sour dough is necessary for the development of characteristic properties of rye breads. Sour doughs contain both heterofermentative lactic acid bacteria and yeasts, and the mixed population usually comprises several different species of both groups. Unlike baker's yeast consisting overwhelmingly of a single yeast species, *S. cerevisiae*, even commercial sour-dough starters are not made of defined pure cultures. *Lactobacillus brevis* and *L. sanfrancisco* are characteristic lactic acid bacteria in sour dough, whereas *Candida milleri* and *S. exiguus* are the predominant yeast species.

Yeast Starter Cultures

While about 1.5 million tons of baker's yeast are produced annually throughout the world, the estimated production of yeast starter cultures is less then 1000 tons, although these are made commercially in many countries. Wine starter cultures are used to initiate the fermentation of must instead of a natural (spontaneous) process. The use of yeast starter cultures in wine-making has increased strongly over the last decade. Freeze-dried or active dry yeast starters are made of selected strains of various useful technological properties, such as a tolerance of high concentrations of ethanol, sugar, and sulfur dioxide, low temperature, etc. Their use is also advantageous in sparkling-wine production.

The use of dried yeast in breweries is not common, although it may offer advantages such as yeast availability, flexibility, and cost-effectiveness in particular for producing specialty beers in small quantities.