FERMENTED FOODS AND THEIR PROCESSING

Nduka Okafor
Nnamdi Azikiwe University, Awka, Nigeria

Keywords: Fermented foods, bread, garri, ogi, koko, dawadawa, foo-foo, maize, sorghum, cassava, wheat, cassava, cheese, milk, vinegar, fish sauce, shoyu, idli, oncom, fermented milks, lactic acid bacteria, starter cultures, tea, coffee, cocoa, sauerkraut, pickled cucumber.

Contents

Summary

Fermented foods are foods produced by the activity of microorganisms, which while forming only a small proportion of the total weight of the foods, have a profound effect on the character of the foods. This article has discussed fermented foods from around the world, including foods from wheat, maize, sorghum, cassava, soybeans, vegetables, fish, milk and alcohol.

1. Introduction

Fermented foods may be defined as foods which are processed through the activity of microorganisms. The weight of the microorganisms in the food is usually small, but their influence on the nature of the food, especially in terms of flavor and other organoleptic properties, is profound. In terms of this definition, mushrooms [see also - *Mushroom production*] cannot properly be described as fermented foods as they form the bulk of the food and do not act on a substrate which is consumed along with the organism. In contrast, yeasts form a small proportion by weight on bread, and are responsible for the flavor of bread; hence bread is a fermented food.

Fermented foods have been known from the earliest period of human existence, and exist in all societies. Fermented foods have several advantages:

- fermentation serves as a means of preserving foods in a low cost manner; thus cheese keeps longer than the milk from which it is produced;
- the organoleptic properties of fermented foods are improved in comparison with the raw materials from which they are prepared; cheese for example, tastes very different from milk from which it is produced;
- fermentation sometimes removes unwanted or harmful properties in the raw material; thus fermentation removes flatulence factors in soybeans, and reduces the poisonous cyanide content of cassava during garri preparation (see below);
- the nutritive content of the food is improved in many foods by the presence of the microorganisms; thus the lactic acid bacteria and yeasts in garri and the yeasts in bread add to the nutritive quality of these foods;
- fermentation often reduces the cooking time of the food as in the case of fermented soybean products, or ogi the weaning West African food produced from fermented maize.

Fermented foods are influenced mainly by the nature of the substrate and the organisms involved in the fermentation, the length of the fermentation and the treatment of the food during the processing.

2. Fermented food from cereals

2.1 Wheat

Bread has been known to man for many centuries and excavations have revealed that baking ovens were in use by the Babylonians, about 4,000 B.C. Today, bread supplies over half of the caloric intake of the world's population including a high proportion of the intake of Vitamins B and E. Bread therefore is a major food of the world.

2.1.1 Ingredients for Modern Bread-making

The basic ingredients in bread-making are flour, water, salt and yeasts. In modern bread-making however a large number of other components and additives are used as knowledge of the baking process has grown. These components depend on the type of bread and on the practice and regulations operating in a country. They include "yeast food", sugar, and milk, eggs, shortening (fat) emulsifiers, anti-fungal agents, anti-oxidants, and enzymes, flavoring and enriching ingredients. The ingredients are mixed together to form dough which is then baked.

Flour is the chief ingredient of bread and is produced by milling the grains of wheat, various species and varieties of which are known. For flour production most countries use *Triticum vulgare.* A few countries use *T.durum*, but this yellow colored variety is more familiarly used for semolina and macaroni in many countries. The chief constituents of flour are starch (70 per cent), protein (7-15 per cent), sugar (1 per cent) and lipids (1.0 per cent).

In bread-making from *T. vulgare* the bread-making quality of the flour depends on the quality and quantity of its proteins. Flour proteins are of two types. The first type, forming

about 15 per cent of the total, is soluble in water and dilutes salt solutions, and is non-dough forming. It consists of albumins, globulins, peptides, amino acids and enzymes. The remaining 85 per cent are insoluble in aqueous media and are responsible for dough formation. They are collectively known as gluten. It also contains lipids.

Gluten has the unique property of forming an elastic structure when moistened with water. It forms the skeleton which holds the starch, yeasts, gases and other components of dough. Gluten can be easily extracted, by adding enough water to flour and kneading it into dough. After allowing the dough to stand for an hour the starch can be washed off under a running tap water leaving a tough, elastic, sticky and viscous material which is the gluten. Gluten is separable into an alcohol soluble fraction which forms one third of the total and known as gladilins and a fraction (2/3) that is not alcohol-soluble and known as the glutenins. Gladilins are of lower molecular weight than glutenins; they are more extensible, but less, elastic than glutenins. Glutelins are soluble in acids and bases whereas gladenins are not. The latter will also complex with lipids, whereas glutelins do not.

"Hard" wheat with a high content of protein (over 12 per cent) is best for making bread because the high content of glutenins enables a firm skeleton for holding the gases released curing fermentation. "Soft" wheat with low protein contents (9-11 per cent) is best for making cakes.

The **yeasts** used for baking are strains of *Saccharomyces cerevisiae*. The ideal properties of yeasts used in modern bakeries are as follows:

- ability to grow rapidly at room temperature of about 20-25°C;
- easy dispersability in water;
- ability to produce large amounts of CO_2 rather than alcohol in flour dough;
- good keeping quality i.e. ability to resist autolysis when stored at 20°C;
- ability to adapt rapidly to changing substrates such as are available to the yeasts during dough making
- high invertase and other enzyme activity to hydrolyze to higher glucofructans rapidly;
- ability to grow and synthesize enzymes and coenzymes under the anaerobic conditions of the dough;
- ability to resist the osmotic effect of salts and sugars in the dough;
- high competitiveness i.e. high yielding in terms of dry weight per unit of substrate used

The name yeast "food" is something of a misnomer, because these ingredients serve purposes outside merely nourishing the yeasts. In general the "foods" contain a calcium salt, an ammonium salt and an oxidizing agent. The bivalent calcium ion has a beneficial strengthening effect on the colloidal structure of the wheat gluten. The ammonium is a nitrogen source for the yeast. The oxidizing agent strengthens gluten by its reaction with the proteins' sulphydryl groups to provide cross-links between protein molecules and thus enhances its ability to hold gases released during dough formation. Oxidizing agents which have been used include iodates, bromates and peroxide. A commonly used yeast food has the following composition: calcium sulphate, 30 per cent, ammonium chloride,

9.4 per cent, sodium chloride, 35 per cent, potassium bromate, 0.3 per cent; starch (25.3 per cent) is used as a filler.
Sugar is added:

- to provide carbon nourishment for the yeasts additional to the amount available in flour sugar;
- to sweeten the bread;
- to afford more rapid browning (through sugar caramelization) of the crust and hence greater moisture retention within the bread. Sugar is supplied by the use of sucrose, glucose corn syrups (regular and high fructose), depending on availability.

Animal and vegetable fats are added as **shortenings** in bread-making at about 3 per cent (w/w) of flour in order to yield

- increased loaf size;
- a more tender crumb; and
- enhanced slicing properties

Butter is used only in the most expensive breads; lard (fat from pork) may be used, but vegetable fats especially soy bean oil, because of its most assured supply, is now common.

Emulsifiers [Surfactants] are used in conjunction with shortening and ensure a better distribution of the latter in the dough. Emulsifiers contain a fatty acid, palmitic or stearic acid, which are bound to one or more poly functional molecules with carboxylic, hydroxyl, and/or amino groups e.g glycerol, lactic acid, sorbic acid or tartaric acid [see also - *Production of biosurfactants*]. Sometimes the carboxylic group is converted to its sodium or calcium salt. Emulsifiers are added as 0.5 per cent flour weight. Commonly used surfactants include: calcium stearoyl- 2-lactylate, lactylic stearate, sodium stearly fumarate.

Milk to be used in bread-making must be heated to high temperatures before being dried; otherwise, for reasons not yet known, the dough becomes sticky. Milk is added to make the bread more nutritious, to help improve the crust colour, presumably by sugar caramelization and because of its buffering value. Because of the rising cost of milk, skim milk and blends made from various components including whey, buttermilk solids, sodium or potassium caseinate, soy flour and/or corn flour are used. The milk substitutes are added in the ratio of 1-2 parts per 100 parts of flour.

Salt: About 2 per cent sodium chloride is usually added to bread. It serves the following purposes:

- it improves taste;
- it stabilizes yeast fermentation;
- h as a toughening effect on gluten;
- helps retard proteolytic activity, which may be related to its effect on gluten;
- it participates in the lipid binding of dough.

Because of the retarding effect on fermentation, salt is preferably added towards the end of the mixing. For this reason flake-salt which has enhanced solubility is used and is added towards the end of the mixing. Fat-coated salt may also be used; the salt becomes available only at the latter stages of dough or at the early stages of baking.

Water is needed to form gluten, to permit swelling of the starch, and to provide a medium for the various reaction that take place in dough formation. Water is not softened for bread-making because, as has been seen, calcium is even added for reasons already discussed. Water with high sulphide content is undesirable because gluten is softened by the sulphydryl groups.

Sufficient **amylolytic enzymes** must be present during bread-making to breakdown the starch in flour into fermentable sugars. Since most flours are deficient in α- amylase, flour is supplemented during the milling of the wheat with malted barley or wheat to provide this enzyme. Fungal or bacterial amylase preparations may be added during dough mixing. Bacterial amylase from *Bacillus subtilis* is particularly useful because it is heat-stable and partly survives the baking process. Proteolytic enzymes from *Aspergillus oryzae* are used in dough making, particularly in flours with excessively high protein contents. Ordinarily however, proteases have the effect of reducing the mixing time of the dough.

Mold-inhibitors (Antimycotics)*:* The spoilage of bread is caused mainly by the fungi *Rhizopus, Mucor, Aspergillus* and *Penicillium*. Spoilage by *Bacillus mesenteroides* ("ropes) rarely occurs. The main anti-mycotic agent added to bread is calcium propionate. Others used to a much less extent are sodium diacetate, vinegar, monocalcium phosphate, and lactic acid.

Bread is often **enriched** with various vitamins and minerals including thiamin, riboflavin, niacin and iron.

2.1.2 Processes of Bread making

Large-scale bread making is now mechanized virtually the world over. The processes of yeast-leavened bread making may be divided into:

- *Pre-fermentation (or sponge mixing)*: At this stage a portion of the ingredients is mixed with yeast and with or without flour to produce an inoculum. During this time, the yeast becomes adapted to the growth conditions of the dough and rapidly multiplies. Gluten development is not sought at this stage.
- *Dough mixing*: The balance of the ingredients is mixed together with the inoculum to form the dough. This is the stage when maximum gluten development is sought.
- *Cutting and rounding:* The dough formed above is cut into specific weights and rounded by machines.
- *First (intermediate) proofing*: The dough is allowed to rest for about 15 minutes usually at the same temperature as it has been previous to this time i.e. at about 27°C. This is done in equipment known as an overhead proofer.

- *Molding*: The dough is flattened to a sheet and then moulded into a spherical body and placed in baking pan which will confer shape to the loaf.
- *Second Proofing:* This consists of holding the dough for about 1 hour at 35-43°C and in an atmosphere of high humidity (89 - 95 °C)
- *Baking:* During baking the proofed dough is transferred, still in the final pan, to the oven where it is subjected to an average temperature of 215-225°C for 17-23 mins. Baking is the final of the various baking processes. It is the point at which the success or otherwise of all the previous inputs are determined.
- *Cooling, slicing and wrapping:* The bread is de-panned, cooled to 4- 50^0 C sliced (optional in some countries) and wrapped in waxed paper, or plastic bags.

2.1.3 Systems of baking

There are three basic systems of baking. All three are essentially similar and differ only in the presence or absence of a pre-fermentation. Where pre-.fermentation is present, the formulation of the pre-ferment may consists of a broth or it may be a sponge (i.e. includes flour). All three basic types may also be batch or continuous.

1. *Sponge Doughs*: This system or modification of it is the most widely used world-wide. It has consequently been the most widely described. In the sponge dough system of baking, a portion (60-70 per cent) of the flour is mixed with water, yeast food in a slurry tank (or "ingridator") during the pre-fermentation to yield a spongy material due to bubbles caused by alcohol and CO_2 (hence the name). If enzymes are used they may be added at this stage. The sponge is allowed to rest at about 27°C and a relative humidity of 75-80 per cent for 3.5 to 5 h. During this period the sponges rise 56 times because of the volatile products released by this yeast and usually collapse spontaneously. During the next (or dough) stage the sponge is mixed with the other ingredients. The result is formation of a dough which follows the rest of the scheme described above. The heat of the oven causes the metabolic products of the yeast - CO_2, alcohol, and water vapor to expand to the final size of the loaf. The protein becomes denatured beginning from about 70°C; the denatured protein soon sets, and imposes fixed sizes to the air vesicles. The enzymes α- and β-amylases are active for a while as the temperature passes through their optimum temperatures, which are 55-65°C and 65-70°C respectively. At temperatures of about 10^0 C beyond their optima, these two enzymes become denatured. The temperature of the outside of the bread is about 195°C but the internal temperature never exceeds 100^0 C. At about 65-70^0 C the yeasts are killed. The higher outside temperature leads to browning of the crust, a result of reactions between the reducing sugars and the free amino acids in the dough. The starch granules which have become hydrated are broken down only slightly by the amylolytic enzymes before they become denatured to dextrin and maltose by α- amylase and β- amylase respectively.

2. *The liquid ferment system*: In this system water, yeast, food, malt, sugar, salt and, sometimes, milk are mixed during the pre-fermentation at about 30°C for about 6 hours. After that, flour and other ingredients are added and mixed to form a dough. The rest is as described above.

3. *The Straight Dough System*: In this system, all the components are mixed at the same

until a dough is formed. The dough is then allowed to ferment at about 28-30°C for 2-4 hours. During this period .the risen dough is occasionally knocked down to cause it to collapse. Thereafter it follows the same process as those already described. The straight dough is usually used for home bread making.

The Chorleywood Bread Process is a unique modification of the straight dough process, which is used in most bakeries in the United Kingdom and Australia. The process, also know as CBP (for Chorleywood Bread Process) was developed at the laboratories of the Flour Milling & Baking Research Association (at Chorleywood, Hertfordshire, U.K.) as a means of cutting down baking time. The essential components of the system are that:

- All the components are mixed together with a finite amount of energy at so high a rate that mixing is complete in 3-5 minutes.
- Fast-acting oxidizing agents (potassium iodate or bromate, or more usually ascorbic acid) are used.
- The level of yeast added is 50-100 per cent of the normal level; often specially developed fast-acting yeasts are employed.
- No pre-fermentation time is allowed and the time required to produce bread from flour is shortened from 6-7 hours to 1½-2 hours.

2.1.4 Role of Yeasts in Bread making

The primary role of yeasts in bread making is leavening. Leavening is the increase in the size of the dough induced by gases by the metabolism of yeasts. During Bread making yeasts ferment hexose sugars mainly into alcohol, carbon dioxide and smaller amounts of glycerol and trace compounds of various other alcohols, esters aldehydes and organic acids. The CO_2 dissolves continuously in the dough, until the latter becomes saturated. Subsequently the excess CO_2 in the gaseous state begins to form bubbles in he dough. It is this formation of bubbles which causes the dough to rise or to leaven. The total time taken for the yeast to act upon the dough varies from 2-6 hours or longer depending on the method of baking used.

Factors which effect the leavening action of yeasts are*:*

a) *The nature of the sugar available*: When no sugar is added to the dough such as in the traditional method of bread making, or in sponge of sponge-doughs and some liquid ferments, the yeast utilizes the maltose in the flour. Such maltose is produced by the action of the amylases of the wheat. When however glucose, fructose, or sucrose are added these are utilized in preference to maltose. Sucrose is inverted into glucose and fructose by the saccharase of the cell surface of bakers yeasts. While fructose and glucose are rather similarly fermented, glucose is the preferred substrate.

b) *Osmotic pressure*: High osmotic pressures inhibit yeast action. Baker's yeast will produce CO_2 rapidly in doughs up to a maximum of about 5 per cent glucose, sucrose or fructose or in solutions of about 10 per cent. Beyond that gas production drops off rapidly. Salt at levels beyond about 2 per cent (based on flour) is inhibitory on yeasts. In dough the amount used is 2.0-2.5 per cent (based on flour) and this is inhibitory on yeasts. The level of salt addition is maintained as a compromise for its role in gluten formation. Salt is

therefore added as late as possible in the dough formation process.

c) *Effect of nitrogen and other* nutrients: Short fermentations require no nutrients but for longer fermentation, the addition of minerals and a nitrogen source increases gas production. Ammonium normally added as yeast food is rapidly utilized. Flour also supplies amino acids and peptides and thiamine. Thiamine is required for the growth of yeasts. When liquid pre-ferments containing no flour are prepared therefore thiamine is added.

d) *Effect on fungal inhibitors (anti-mycotic agents):* Anti-mycotics added to bread are all inhibitory to yeast. In all cases therefore a compromise must be worked between the maximum level permitted by government regulations, the minimum level inhibitory to yeasts and the minimum level inhibitory to fungi. A compromise level for calcium propionate which is the most widely used anti-mycotic, is 0.19 per cent (based on flour weight).

e) *Yeast concentration:* The weight of yeast for baking rarely exceeds 3 per cent of the flour weight. A balance exists between the sugar concentration, the length of the fermentation and the yeast concentration. Provided that enough sugar is available, the higher the yeast concentration the more rapid is the leavening. However although the loaf may be bigger the taste and in particular the texture may be adversely affected. Experimentation is necessary before the optimum concentration of a new strain of yeast is chosen.

-
-
-

Bibliography

Anonymous (1993) *Danone World Newsletter* [These newsletters contain much information on fermented milks] Bozoglu, T F and Ray, B (1996) Lactic Acid Bacteria: Current Advances in Metabolism, Genetics and Applications. [A useful source of information on all aspects of Lactic Acid Bacteria]

Harper, W J and Carl, W H (1976) *Dairy Technology and Engineering*. Westport: The Avi Publication Co Inc

Okafor, N (1987) *Industrial Microbiology*. Ife (Nigeria): University of Ife Press [This volume contains information on various fermented foods]

Okafor, N (2006) *Modern Industrial Microbiology and Biotechnology*. Enfield, New Hampshire: Science Publishers

Rehm, H -J and Reed, G (Series editors in cooperation with Puhler, A and Stadtler, P) (1995) *Biotechnology: a Multi-volume Comprehensive Treatise*. Second, Completely Revised Edition. [A most useful source of information: Volume 9 (edited G Reed and T W Nagodawithana: *Enzymes, Biomass, Food and Feed* deals with fermented foods fro around the world]

Ronsivalli, L J and Vieira, E R (1992) Elementary Food Science. New York: Van Nostrand Reinhold

Webb, B H and Whittier, E O (editors) (1970) *Byproducts from Milk*. Westport: The Avi Publication Co Inc [This book contains much information on milk and various milk products]

Wood, B.J.R. (Editor) (1985) *Microbiology of Fermented Foods*, Volumes 1, 371 pp & Volume 2, 292 pp. Elsevier Applied Science Publishers. London and New York. [This two-volume book discusses the microbiology of fermented foods from around the world].

Biographical Sketch

Prof Nduka Okafor was educated at Government College, Ibadan, Nigeria. He obtained his first degree from the University of London, England (at the then University College, Ibadan), and his Ph D degree from the University of Cambridge, England. A charted biologist of the UK, he is a Fellow of several academic bodies including the Nigerian Academy of Science, the World Academy of Art and Science, the Institute of Food Science and Technology, the Institute of Biology.

He has taught and researched in various aspects of microbiology in universities in Nigeria, England, the Netherlands, Austria, Australia and the United States. He has acted as consultant to various United Nations bodies including the United Nations Industrial Development Organization (UNIDO), the World Health Organization (WHO) and the International Atomic Energy Agency (IAEA).

He has published numerous scientific papers, patents and books, including *Industrial Microbiology*, and *Waste and Aquatic Microbiology* and *the Development of Universities in Nigeria.*