Food fermentation: an introduction

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Abstract

Strictly speaking, fermentation relates to anaerobic energy metabolism. In practical terms however, fermentation of foods is defined more broadly as bioprocessing using microorganisms and their enzymes to achieve desirable quality characteristics. Food groups (ingredients) that can be fermented include those of plant and animal origin, whereas the microorganisms used belong to diverse groups, namely bacteria, yeasts and moulds. The microbial metabolism and extracellular enzymes have a significant impact on the composition of fermented foods. Examples of fermented food products will be given, made from various ingredients, originating from various continents and climatological zones, and made using technologies of different levels of sophistication. The fermentation itself usually is only part of a process. Processes consist of unit operations and are organized sequences that can be visualized in flow diagrams. Some of the most important unit operations in fermentation processes will be highlighted.

1. Fermentation

Fermentation of food and beverages is one of the oldest ways of food processing. Popular products such as beer, bread, wine and sausages have been around for millenia. Strictly speaking, the term "fermentation" relates to anaerobic energy metabolism only. The word is derived from the Latin "fermentare" (to cause to rise), reflecting the foaming that occurs during the preparation of wine and beer. The fact that the frothing results from the evolution of carbon dioxide gas, was not recognized until the 17th century. Hereafter, it took 2 centuries more until Louis Pasteur discovered that yeasts and other microorganisms were the cause of all this...

Presently, fermentation of foods is defined more broadly as bioprocessing, using microorganisms and their enzymes to achieve desirable quality characteristics. The latter relate to the appeal (attractiveness), utility and functionality of the fermented food. Appeal relates to the exterior, texture, odour and taste of food, all very important aspects that are detectable by the senses and that satisfy the consumer. Utility aspects include the reduction of bulk volume, shortening the cooking time, lengthening the shelf-life, improvement of nutrient retention, and the opportunity to turn by-products ("waste") into palatable value-added food products. These aspects may not be a driving force in present-day affluent societies, but they are quite important in developing countries where cooking fuel is scarce, and resources limited (Steinkraus, 1995). Functionality of fermented food relates to food safety, digestibility, probiotic effects and other desirable impacts on the health and physiology of the consumer (Farnworth, 2003). The functionality aspects are probably a major reason why people have always had good experiences with fermented foods and continue to cherish them.

2. Fermentation processes and products

Fermentation bioprocessing requires several essential elements. First of all, the composition of the food, the microorganisms and water are most important. But in addition, numerous process operations are required, including physical, biological and thermal operations in an organized and sequential way: that's what makes it a process.

Among the microorganisms all groups, namely bacteria, yeasts and moulds are encountered as functional microorganisms in food fermentations. Among the bacteria, the lactic acid bacteria are the most widely distributed in home-scale and industrial processing of fermented dairy, meat, vegetable, and cereal products; of the yeasts, *Saccharomyces cerevisae* (baker's or brewer's yeast) is the most important in the making of alcoholic beverages and the leavening of bread; in mould fermented foods *Aspergillus* species, *Penicillium* as well as some of the Mucorales are widely used for the production of a variety of products such as cheeses, wines, and soybean foods. The microbial metabolism and extracellular enzymes have a significant impact on the composition of fermented foods because they cause decomposition of macromolecular food components (polysaccharides, proteins, lipids) into smaller compounds (dextrins, sugars, peptides, amino acids, free fatty acids), and accumulate a scala of metabolites (acids, alcohols, esters, aldehydes, ketones, vitamins, etc.).

Many foods are fermented naturally, i.e. without the use of specific starter microorganisms. In such cases the microflora on the ingredients are favoured and some of them will dominate and form the characteristic properties of the product. Although this is a cheap technique that can be applied in simple environments, product quality and safety cannot be predicted or standardized. For larger-scale and standardized fermentations, the use of better defined starter microorganisms is indispensible. In such settings, the ingredients will first be pre-treated to reduce their load of unwanted microorganisms, followed by inoculation with selected and activated pure cultures of starter microorganisms. In order to ensure their effect, we must protect the fermentation against contamination from the environment; rather expensive equipment and know-how are required to realize this.

The fermentation itself is part of a larger manufacturing process. Processes consist of unit operations and are organized sequences that can be visualized in flow diagrams. Unit operations in fermentation processes include physical, bioprocessing and thermal operations; physical operations include transport, grading, sorting, cleaning, washing, separations, size reduction, mixing and so on. Bioprocessing operations are carried out by the microorganisms and their enzymes: they include the uptake and removal of substrates, the production of metabolites and degradation products, the synthesis of complex substances (vitamins, pigments, enzymes, polysaccharides), the production of biomass, and the enzymatic modification of food components. Thermal operations include heating and cooling, for example blanching, pasteurization, cooking, roasting and frying; but also refrigeration and freezing can be very important to stop fermentations, or preserve ingredients and products.

Food groups (ingredients) that can be fermented include those of plant and animal origin (Wood, 1998). Examples of fermented food products are listed in Table 1 and shown in Figure 1. They are made from various ingredients, originate from all continents and climatological zones, and are made with different levels of technologies. Some specific products include sauerkraut, sausage, beer, soumbala, soy sauce and sufu. Sauerkraut ("sour cabbage") represents a diversity of lactic acid fermented vegetables found in many places in the world; it is made by natural fermentation in which lactic acid bacteria dominate. Sausages, made from pork or other meats, are often made from raw meat and are made safe and palatable using a mixture of curing (application of salts and nitrite) and fermentation, mostly by lactic acid bacteria. Beer is a collective name for low alcoholic (usually 2-8 % v/v), effervescent beverages made from cereals such as barley, wheat, sorghum, millet, etc. It can be made in the household kitchen but most beer is made at a very large scale in breweries using pure culture brewing yeasts. Soumbala is a lesser-known West-African product obtained by fermentation of locust beans (seeds from the tree *Parkia biglobosa*) with *Bacillus subtilis*, and used as a flavouring ingredient for soups and sauces. Soy sauces are better known internationally because their manufacturing process has been industrialized and soy sauces are distributed world-wide; they could be described as flavoursome protein digests in a salty solution. Especially the free amino acids such as glutamic acid make soy sauce very tasty and capable of enhancing the meaty taste of - for example - chicken. Finally, Chinese Sufu or Furu is not yet very well known outside China, but locally it is a popular side-dish that offers taste as well as nutrition. It is made by mould fermentation of tofu (soybean curd) which is gradually matured (degraded) by the mould enzymes.

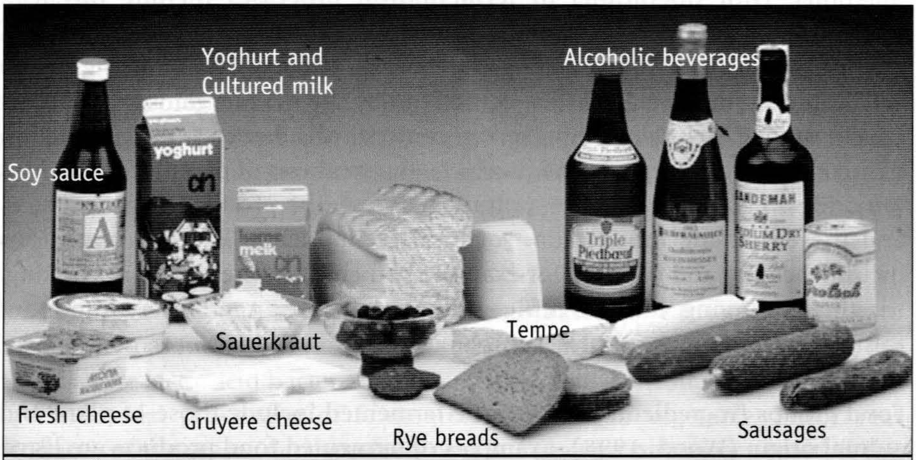

Figure 1. Range of fermented foods.

3. Issues of interest

Some of the present issues in the area of food fermentation include the safety of traditional fermented foods (Adams and Nout, 2001), the use of molecular techniques to monitor the fate of functional as well as contaminating microflora during fermentation and storage of the fermented products, the contribution of fermented food (components) to human and animal health, the legal aspects of the use of functional food (ingredients) and international legislation regarding labeling, the tailor-made design of fermentation processes and the composition of fermented food products, and the role that "omics" can play in the future development of safe and healthy foods.

The course on food fermentation, as described in this volume, aims to address several of these issues, and is therefore organized along a few thematic lines. These are:

1. biodiversity of lactic acid bacteria and yeasts;
2. product technology of exotic (African), naturally fermented (sourdough) and starter-mediated (dairy) foods;
3. functionality particularly health, flavour and legislative aspects;
4. models and control of fermentation processes and product quality;
5. and omics, with emphasis on proteomics, genomics, metabolomics and future prospects.

Table 1. Examples of fermented foods.

Food group	Fermented materials	Specific examples
milk	fermented milks	yoghurt, kefir
	cheese	Gouda, Camembert
meats	sausages	salami
fish	sauces and pastes	nuoc-mam, terasi
	marinades	katsuobushi
vegetables	cabbage	sauerkraut
	gherkins	pickles
	olives	olives
rootcrops and tubers	cassava	gari
	potatoes	wodka
cereals	barley	lager beer
	rice	saké
	maize	ogi
leguminous seeds	soya beans	soysauce, miso
fruits	apple	cider
	grape	wine
	pear	perry

References

Adams, M. R., and Nout, M. J. R., eds. (2001) *Fermentation and Food Safety.* Gaithersburg, Md.: Aspen Publishers, Inc.

Farnworth, E. R., ed. (2003) *Handbook of fermented functional foods.* Boca Raton: CRC Press.

Steinkraus, K. H. (1995) *Handbook of indigenous fermented foods.*, second ed., revised and expanded/Ed., New York: Marcel Dekker.

Wood, B. J. B. (1998) Protein-rich foods based on fermented vegetables. In *Microbiology of Fermented Foods* ed. B. J. B. Wood, Vol. 2, pp. 484-504. London: Blackie Academic & Professional.