

Title of the topic: Fermented Products

Short Summary

Fermentation is an ancient biotechnology used to preserve food, enhance flavors, and improve nutritional value. It involves microorganisms such as bacteria, yeasts, and moulds that convert raw food materials into stable, safe, and palatable products. Lactic acid bacteria, yeasts like *Saccharomyces* and moulds like *Aspergillus* and *Penicillium* play key roles in different fermentation processes. Traditional fermented foods such as kimchi, sauerkraut, sinki, natto, and miso demonstrate the diversity of fermentation methods and microbial involvement. These foods not only have extended shelf life but also provide health benefits due to bioactive compounds and improved digestibility.

Learning Objectives

1. To understand the concept and importance of food fermentation.
2. To recognize traditional fermented foods and their preparation methods.
3. To understand the nutritional and health benefits of fermented foods.

Learning Outcomes

1. Students will understand the microbial processes involved in common fermented foods.
2. Students will analyse the role of fermentation in enhancing nutritional quality.
3. Students will apply knowledge of fermentation to identify or prepare basic fermented foods.

Introduction

History and scope of fermented foods

Fermentation is one of the oldest biotechnologies for the production of food products with desirable properties such as extended shelf-life and good organoleptic properties (Smid and Hugenholtz 2010). Finished fermented foods usually have an improved microbial stability and safety and some can be stored even at ambient temperatures. Furthermore, there are several examples of fermentation processes which lead to an increase in nutritional value or digestibility (Jägerstad *et al.* 2005) of food raw materials. Finally, food fermentation processes also deliver products with increased palatability for consumers. All these arguments have boosted the interest to explore natural food fermentation processes and more precisely to link the diversity of the community of fermenting microbes and their properties to the energetics of the process and to product quality.

Microorganisms Involved in Food Fermentations

The most common groups of microorganisms involved in food fermentation are:

- Bacteria
- Yeasts
- Moulds

Bacteria

Several bacteria are present in foods, the majority of which are concerned with food spoilage, while some like *Clostridium* are the causative agent for production of toxin like botulin, causing botulism in man (Joshi *et al* 2006). As a result, the important role of bacteria in the food fermentations is often overlooked. Lactic acid bacteria like *Lactobacillus*, *Pediococcus*, *Streptococcus*, *Oenococcus*, etc. are the most important bacteria in fermented foods, followed by *Acetobacter* species, which oxidize alcohol to acetic acid. The acetic acid fermentation has been used extensively to produce fruit vinegars including cider vinegar (Joshi and Thakur 2000, Joshi and Sharma 2010). A third group of bacteria of significance in fermentation are the *Bacillus* species (*Bacillus subtilis*, *B. licheniformis* and *B. pumilus*), which bring about

alkaline fermentation *Bacillus subtilis* is the dominant species causing the hydrolysis of protein to amino acids and peptides and releasing ammonia, which increases the alkalinity and makes the substrate unsuitable for the growth of spoilage organisms. Alkaline fermentations are more common with protein-rich foods such as soybeans and other legumes, although there are few examples utilizing plant seeds. For example, water melon seeds (ogiri in Nigeria) and sesame seeds (ogiri-saro in Sierra Leone) are the substrates for alkaline fermentation (Battcock and Azam Ali 2001).

Yeasts

Yeasts and yeast like fungi are widely distributed in nature. They are present in orchards and vineyards, in air and soil, and in the intestinal tract of animals. Like bacteria and moulds, yeasts can have beneficial and non-beneficial effects in food fermentations. Some of the yeasts like *Pichia* are viewed as spoilage of food products while those like *Candida* are utilized for the single cell protein production. The most beneficial yeast in terms of desirable food fermentations are from the *Saccharomyces* family, especially *S. cerevisiae* involved in bread making and alcohol in wine fermentations. *Saccharomyces cerevisiae* var. *ellipsoideus* is employed extensively in wine making (Joshi *et al.* 2011). *Schizosaccharomyces pombe* and *S. boulderi* are the dominant yeasts in the production of traditional fermented beverages, especially those derived from maize and millet (Battcock and Azam Ali 2001).

Saccharomyces cerevisiae var. *carlbergensis* is the yeast involved in beer production.

Schizosaccharomyces pombe has been found to have capacity to degrade malic acid into ethanol and carbon dioxide, and has been used successfully to lower the acidity in the grape and plum musts (Vyas and Joshi 1988, Joshi *et al.* 1991). A number of yeasts like *Rhodotorula*, *Cryptococcus* have capacity to produce pigment to be used as biocolour (Joshi *et al.* 2003)

Moulds

Moulds are also important organisms in food processing both as spoilers and preservers of foods. Many moulds have capacity to produce enzymes of commercial importance such as pectinase by *Aspergillus niger* (Joshi *et al.* 2006). Species of *Aspergillus* are involved in the production of citric acid from waste like apple pomace (Joshi *et al.* 2009, Joshi and Attri 2006). The *Aspergillus* species are often responsible for undesirable changes in foods causing spoilage. On the other hand, *Penicillium* species are associated with the ripening and flavour development in cheeses. While the species of *Ceratocystis* are involved in fruit flavour

production, at the same time, *Penicillium* is the causal agent for production of toxin like patulin (Joshi *et al.* 2013).

Traditional Fermented Fruits and Vegetables

Kimchi

Kimchi is a Korean traditional fermented vegetable made from Chinese cabbage (beachu), radish, green onion, red pepper powder, garlic, ginger, and fermented seafood (jeotgal), which is traditionally made at home and served as a side dish at meals. Kimchi is a generic term indicating a group of traditional LA fermented vegetables in Korea. The major raw materials (oriental cabbage or radish) are salted after prebrining, blended with various spices (red pepper, garlic, green onion, ginger, etc.) and other minor ingredients (seasonings, salted sea foods, fruits and vegetables, cereals, fish, and meats, etc.), and then fermented at low temperature (2–5°C). Kimchi fermentation is temperature-dependent process. It ripens in one week at 15°C and took three days at 25°C. But low temperature is preferred in kimchifermentation to prevent production of strong acid, overripening, and extended period of optimum taste. Kimchi is characterised particularly by its sour, sweet, and carbonated taste and differs in flavour from sauerkraut and pickles that are popular fermented vegetables. The classical identification of bacterial isolates from kimchi revealed that *Leuconostoc mesenteroides* and *Lactobacillus plantarum* were the predominant species. Several results suggested that LAB contributing to kimchi fermentation include *L. mesenteroides*, *L. citreum*, *L. gasicomitatum*, *Lactobacillus brevis*, *L. curvatus*, *L. plantarum*, *L. sakei*, *L. lactis*, *P. pentosaceus*, *W. confusa*, and *W. koreensis*. Some important species thought to be responsible for kimchi fermentation are *Leuconostoc mesenteroides*, *L. pseudomesenteroides*, and *L. lactis*, as the pH gradually falls to 4.0.

Kimchi contains various health-promoting components, including β -carotene, including β -carotene, chlorophyll, vitamin C, and dietary fibre. In addition, antimutagen, antioxidation, and angiotensin-converting enzyme inhibition activities of kimchi are thought to protect against disease. Bacteria isolated from kimchi produce beneficial enzymes, such as dextranucrase and alcohol/acetaldehyde dehydrogenase. Because of these beneficial properties, kimchi was nominated as one of the world's healthiest foods in a 2006 issue of Health Magazine. Optimum taste of kimchi is attained when the pH and acidity reach approximately 4.0–4.5 and 0.5–0.6, respectively. Vitamin C content is maximal at this point.

Sauerkraut

Sauerkraut means sour cabbage. In sauerkraut fermentation, fresh cabbage is shredded and mixed with 2.3–3.0% salt before allowing for natural fermentation. Sauerkraut production typically relies on a sequential microbial process that involves heterofermentative and homofermentative LAB, generally involving *Leuconostoc* spp. in the initial phase and *Lactobacillus* spp. and *Pediococcus* spp. in the subsequent phases. The pH of final product varies from 3.5 to 3.8. At this pH, the cabbage or other vegetables will be preserved for a long period of time. Sauerkraut brine is an important byproduct of the cabbage fermentation industry and can be used as a substance for the production of carotenoids by *Rhodotorula rubra* or for β -glucosidase production by *Candida wickerhamii* for commercial applications.

Sinki

Sinki, an indigenous fermented radish tap root food, is traditionally prepared by pit fermentation, which is a unique type of biopreservation of foods by LA fermentation in the Sikkim Himalayas. For sinki production, a pit was dug with 2-3 ft diameter in a dry place. The pit is cleaned, plastered with mud, and warmed by burning. After removing the ashes, the pit is lined with bamboo sheaths and paddy straw. Radish tap roots are wilted for 2-3 days, crushed, dipped in lukewarm water, squeezed, and pressed tightly into the pit, covered with dry leaves and weighted down by heavy planks or stones. The top of the pit is plastered with mud and left to ferment for 22–30 days. After fermentation, fresh sinki is removed, cut into small pieces, sun-dried for 2-3 days, and stored at room temperature for future consumption. Pit fermentation has been practiced in the South Pacific and Ethiopia for preservation of breadfruit, taro, banana, and cassava. Sinki fermentation is carried out by various LAB including *L. plantarum*, *L. brevis*, *L. casei*, and *Leuconostoc fallax*

Natto

Natto is a traditional Japanese fermented soybean, of which Itohiki-Natto is the most commonly consumed (Cao *et al.*, 201). Natto is produced through fermentation of cooked yellow soybeans with *Bacillus subtilis* var. natto. This produces a viscous food with a distinct flavour and strong odour (Kada *et al.*, 2008). Natto characteristics vary according to soybean steaming time, relative humidity, fermentation time and temperature (Cao *et al.*, 201). The fermentation of Natto produces a number of bioactive factors, including nattokinase, bacillopeptidase F, vitamin K₂ and dipicolinic acid (Cao *et al.*, 201). Furthermore, the quantity of the isoflavone genistein, with purported associations with metabolic and

inflammatory disorders and carcinogenesis (Mukund *et al.*, 2017), is greater in Natto compared to unfermented soy products (Fukutake *et al.*, 1996).

Miso

Miso is a traditional Japanese paste of fermented soybean used to make miso soup. Miso is produced by fermenting soybeans with 'Koji', produced from a mould *Aspergillus oryzae*, although *Saccharomyces cerevisiae* and lactic acid bacteria may additionally be used. As with other fermented soy foods, miso production varies greatly in terms of ingredients, temperature and fermentation time, salt concentration and the strain of *A. oryzae* used.

A microbial analysis of miso at different time points following the start of fermentation revealed *Bacillus subtilis*, *Bacillus amyloliquefaciens*, *Staphylococcus gallinarum* and *Staphylococcus kloosii* to be present during fermentation, with only the *Bacillus* species remaining in the final product (Onda *et al.*, 2003). A range of miso samples have also been shown to contain *Lactococcus* sp. GM005, which produces a bacteriocin with strong antibacterial activity that inhibits the growth of a range of bacteria, including *Bacillus subtilis*, *Pediococcus acidilactici* and *Lactobacillus plantarum* (Onda *et al.*, 2002).

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