APPLICATIONS OF BIOTECHNOLOGY TO TRADITIONAL FERMENTED FOODS

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Lesser-Known Fermented Plant Foods

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In many parts of the world, fermented foods form an important part of the diet. These foods are made from plant and animal materials in which bacteria, yeasts, and molds play an important role by modifying the material physically, nutritionally, and organoleptically.

Fermented plant foods may be classified into groups as (a) those made from cereal grains (maize, sorghum, millet, rice, wheat), such as *pozol* (Mexico), *kenkey, ogi,* and *injera* (Africa); (b) those made from pulses, nuts, and other seeds, such as *ontjom* (Indonesia) and *dawadawa* (Savannah Africa); (c) those from tubers (cassava, aroids, potatoes), such as *gari* (Africa) and *farinha puba* (Brazil, Peru, and Ecuador); (d) those from fruits and vegetables, such as *gundruk* (Nepal) and *kimchi* (Korea, East Asia); and (e) beverages derived from tree saps, such as *nipa* wine (Far East) and *pulque* (Mexico).

Most traditional fermented plant foods are prepared by processes of solid-substrate fermentation in which the substrate is allowed to ferment either spontaneously (usually African or Latin American processes) or by adding a microbial inoculum (Far East, South Asia, and Southeast Asia).

Cereal grains account for more than 60 percent of food materials used in the preparation of indigenous fermented foods in Africa. Although maize is a comparatively well-researched crop, no significant research has been done on some of the important traditional crops, such as sorghum and millet (1). *Tef* (*Eragrostis tef*), a staple food grain of Ethiopian subsistence farmers, is still relatively less well known.

Many indigenous fermented foods, some of which long predate recognition of the existence of microorganisms, are eaten in various parts of the world. Increasing interest in this field is reflected in the range of publications (2-10). This paper presents information on some of the lesser-known fermented plant foods that are still produced and

marketed on a small scale and that serve as a staple diet for millions of people in developing countries.

REGIONAL PERSPECTIVES

Cereals are major staples in many developing countries, and the fermentation of cereal grains to prepare a variety of foods has a long history. Fermented products from maize are usually found in Africa and Central and South America and those from sorghum (guinea corn) and millet in Africa and South Asia. Food fermentations based on rice are practiced in India, China, Southeast Asia, and the Far East, while those from wheat are particularly important in the Middle East, Turkey, and the Far East (11).

Fermented foods from tubers are usually found in Africa, among the Andean Indians and in the South Pacific, and the process of detoxification of the tuber before fermentation is still carried out by soaking in water.

Chica, an alcoholic beverage made from maize in Peru since pre-Hispanic times, also is produced from potato, *oca* (*Oxalis tuberosa*), *arracacha* (*Arracacia xanthorrhiza*), *maca* (*Lepidium evenii*), and other Incan crops that science has almost totally neglected. Although cassava and sweet potatoes provide nourishment for more than 500 million people, only a small proportion of this highly perishable staple crop is used in food fermentations in Africa and Latin America.

Legumes account for a substantial amount of food protein intake in developing countries. Of the total world production of over 58 million metric tons in 1990, developing countries produced 62 percent, together with 54 percent of world nut production (12). Fermented products from legumes are not as popular in Africa or Latin America as in the Far East and South and Southeast Asia, where soybean, for instance, is used extensively in the production of fermented products such as soy sauce, *miso*, and *tempe*, and black gram dhal for the production of *idli* and *dosa*. Fermented seed products, however, are often used as condiments in Savannah Africa.

In the tropics, highly perishable foods such as fruits and vegetables may be preserved as fermented products. Some fermented vegetables provide vitamins, particularly during long cold months in the northern parts of East Asia, and others are consumed as part of traditional family life in Southeast Asia. In Mexico refreshing beverages are prepared from a variety of fruits, including pineapples, apples, and oranges.

PRODUCTS FROM CEREAL GRAINS

Ahai

Ahai is a sweet, malty-tasting beverage brewed from maize in Southern Ghana and is usually served as a welcome drink and at outdoor ceremonies, wakes, and funerals. Whitby (13) has reported that the traditional method of preparing *ahai* is much the same as for *pito*, an acid-alcohol beer brewed from sorghum or millet in West Africa, except that *ahai* is not boiled again after fermentation. So far, no studies have been made on the microbiological, biochemical, and nutritional changes that take place during *ahai* production.

Ting

Ting is a staple food for a large proportion of the population of Botswana. It is prepared from maize by natural fermentation. In other regions it is prepared from sorghum or millet. Moss et al. (14) made an extensive study of *ting* fermentation and noted that the success of the fermentation depends on a number of factors, among which temperature is very important.

The microbiology of *ting* fermentation is well documented, but further studies need to be carried out, particularly on the nutritional value. *Ting* may be similar, nutritionally, to other acid-fermented cereal gruels like *kenkey* (West Africa), *kisra* (Sudan), and *pozol* (Mexico).

Maasa

Maasa is a snack food made from millet or sorghum and is very popular in Savannah Africa, particularly during Ramadan. The method of preparation of *maasa* has been reported (9), but there is no information on the microbiology and biochemistry of this fermented product.

There are hundreds of fermented products from cereal grains in the tropical regions of the world that require extensive studies on methods of preparation and biochemical, microbial, and nutritional changes. These include the West African *fura* or *fula, jamin-bang* of the Kaingang Indians of Brazil, and the Maori's *kaanja-kopuwai*, a process of fermenting maize in water prior to eating. The Maoris claim *kaanja-kopuwai* is health giving, and many of the older people attribute their age to this part of their diet.

PRODUCTS FROM ROOT TUBERS

Farinha puba

Farinha puba is a coarse flour made from cassava and is found in the Amazonian regions of Brazil, Peru, and Ecuador. Woolfe and Woolfe (15) presented an outline on the preparation of *Farinha puba*, which is also known as *farinha de mandioca* in Brazil. They noted that the technology was exported to West Africa in the nineteenth century and presumably adapted locally to give the *gari* process. *Gari*, a popular West African staple food that is also eaten in other tropical African countries, is prepared by fermenting cassava; details of improved methods of production are given by Steinkraus et al. (6).

The processes involved in the production of *farinha puba* and *gari* are similar, but unlike *gari* very little information has been published on the methods of production and on the microbiology, nutritional values, and toxicological problems of *farinha puba*. It has been reported that cassava fermentation as practiced in Africa, Asia, and Latin America (16) is an unreliable detoxification method, and the process further reduces the already low protein content. Other studies have shown that cassava fermentation for *gari* production does not totally eliminate the cyanide content but reduces it by at least 65 percent (17,18).

Fatalities from cassava poisoning appear to be rare, but long-term toxic effects, (e.g., goiter and cretinism) in cassava-consuming populations may be more serious, especially in the Amazon, where the pressed-out juices are used for making soups and stews (15). In Africa the pressed-out juice is often used for the production of cassava starch for laundry purposes. The use of pure microbial cultures under controlled fermentation conditions might bring about not only complete hydrolysis of the poisonous glycoside but also an enhanced fermentation process.

Kokonte

Kokonte, another important cassava-based staple, is eaten by millions of people in Savannah Africa. Like many other fermented foods, *kokonte* (Ghana) is known by various names such as *ilafun* (Nigeria) and *icingwadal* (East Africa). The method of preparation of *kokonte* has been reported, but further studies need to be done, particularly on microflora and production of mycotoxins during fermentation (19,20).

Masato (masata)

Masato, or cassava beer, is an alcoholic beverage produced from cassava in the Amazon. It has an alcohol content of 6 to 12 percent by volume and is offered to guests as a sign of hospitality. It is considered an offense to refuse a drink (15). In Brazil it is called *kaschiri* and in Mozambique *masata*. Preparation of *masato* is similar to that of *chica* by the Andean Indians. As a first step of fermentation, cassava is chewed and spat out by women. In Mozambique women chew the yucca plant to produce a similar product.

So far, no scientific account of the *masato* fermentation process has been published. Studies on improving the traditional methods of production are necessary to save this ancient art of the Andean Indians from extinction.

Chuno

Chuno is a food product from potato prepared by the inhabitants of the high Andes of Peru, Chile, Ecuador, Colombia, and Bolivia. An outline of the method of production has been reported, but the microorganisms involved in the fermentation are still not known (9).

The Incan anu (*Tropaecolum tuberssum*) is a tuber that must be fermented before being eaten baked, fried, or added to stew (21). The crop is cultivated in Colombia, Peru, and Bolivia and is also grown as a flowering ornament in Britain and the United States. The fermentation involved during "curing" has not been reported.

PRODUCTS FROM LEGUMES, PULSES, AND OTHER SEEDS

In Savannah Africa, fermented products from legumes and other seeds are important food condiments and are generally strong smelling. Quite often seeds that are used for fermentation are inedible in their raw unfermented state. Fermentation of the West and Central African *iru* or *dawadawa* is similar to the Japanese *natto*, and there is adequate literature on the preparation, biochemistry, microbiology, and industrialization of *iru*. Other indigenous products that are receiving some attention include *ugba* (African oil bean seed), *ogiri* (seeds of watermelon), *ogiri-igbo* (castor oil seed), and *ogiri-nwan* (fluted pumpkin beans).

Lupins (*Lupinus mutabilis*), which are native to the Andes, contain bitter alkaloids and can cause toxicity problems. Lupin seeds are

debittered by soaking them in running water, a process similar to the Maoris' process for corn fermentation and the Ichunol methods of Peru and Bolivia. So far, no report has been published on the debittering of lupins by fermentation, but the soaking may involve some fermentation.

Kenima is a Nepalese fermented product from legumes. There is no published information on the method of preparation, microbiology, and nutritional value.

PRODUCTS FROM FRUITS AND VEGETABLES

Colonche is a sweet fizzy beverage produced in Mexico by fermenting the juice of tunas (fruits of the prickly pear cacti, mainly *Opuntia* species). *Tepache* is also a refreshing beverage prepared originally from maize but from various fruits and is consumed throughout Mexico.

Although some studies have been made on these products (22), it appears that more work is needed, particularly on the biochemical and nutritional changes that take place during the preparations.

The Nepalese pickle or *gundruk* is a fermented dried vegetable served as a side dish with the main meal and is also used as an appetizer in the bland starchy diet. Several hundred tons of *gundruk* is produced annually, and production is still at the household level. Dietz (23) reported on the method of preparation and the role of *gundruk* in the diet of Nepalese people. It has been found that a disadvantage of the traditional process is loss of 90 percent of the carotenoids. Improved methods and further studies might help reduce vitamin loss.

COMMERCIALIZATION

To industrialize some of these fermented plant foods from traditional processes, extensive studies must be made to determine the essential microorganisms, optimum fermentation conditions, biochemical changes, nutritional profile, and possible toxicological problems associated with certain plant materials or the fermented product itself.

Commercial or large-scale processes for indigenous fermented foods need to be adapted to specific local circumstances. Advantages of industrialization include a product with an extended shelf life, maximum utilization of raw materials, production of important by-products, and bioenrichment or fortification of a product for specific consumers such as special diets, weaning foods and exclusion of or reduction in the

levels of mycotoxins. Mycotoxins appear to be a major problem in some fermented products, particularly those of cereal and root tuber origin.

Studies in Japan on *okara*, a by-product of the tofu industry, have shown that fermenting it with *tempe* fungus could result in a product that is useful as a high-fiber, low-energy food material (24).

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Lactic Acid Fermentations

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Lactic acid bacteria perform an essential role in the preservation and production of wholesome foods. The lactic acid fermentations are generally inexpensive, and often little or no heat is required in their preparation, making them fuel efficient as well. Foods fermented with lactic acid play an important role in feeding the world's population on every continent.

Lactic acid bacteria perform this essential function in preserving and producing a wide range of foods: fermented fresh vegetables such as cabbage (sauerkraut, Korean *kimchi*); cucumbers (pickles); fermented cereal yogurt (Nigerian *ogi*, Kenyan *uji*); sourdough bread and bread-like products made without wheat or rye flours (Indian *idli*, Philippine *puto*); fermented milks (yogurts and cheeses); fermented milk-wheat mixtures (Egyptian *kishk*, Greek *trahanas*); protein-rich vegetable protein meat substitutes (Indonesian *tempe*); amino acid/peptide meat-flavored sauces and pastes produced by fermentation of cereals and legumes (Japanese *miso*, Chinese soy sauce); fermented cereal-fish-shrimp mixtures (Philippine *balao balao* and *burong dalag*); and fermented meats (e.g., salami).

Lactic acid bacteria are generally fastidious on artificial media, but they grow readily in most food substrates and lower the pH rapidly to a point where competing organisms are no longer able to grow. *Leuconostoc*s and lactic streptococci generally lower the pH to about 4.0 to 4.5, and some of the lactobacilli and pedicocci to about pH 3.5, before inhibiting their own growth.

In addition to producing lactic acid, lactobacilli also have the ability to produce hydrogen peroxide through oxidation of reduced nicotinamide adenine dinucleotide (NADH) by flavin nucleotide, which reacts rapidly with gaseous oxygen. Flavoproteins, such as glucose oxidase, also generate hydrogen peroxide and produce an antibiotic effect on other organisms that might cause food spoilage; the lactobacilli themselves are relatively resistant to hydrogen peroxide.