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Potential of Lactic Acid Bacteria in Human Nutrition

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ABSTRACT

Several fermented foods and beverages that incorporate lactic acid bacteria are produced throughout the world. Lactic acid bacteria (LAB) are widely distributed in nature and occur as natural microflora in many fermented foods (fermented milk, cereal fermented food, fermented fruit products, among others). Several thousand fermented foods are said to be in existence and are classified as beverages, fruits and processed foods, such as cereal, dairy food, fish, vegetables, beans, meat, starch-added crops and others. In addition to fungi and yeast LAB are also deeply related to human history and have made a great contribution to food fermentation, and to the improvement of its flavor. LAB have been, and are of interest in the promotion of good health in animals and humans. LAB may be used as probiotics, whose positive effects include: growth promotion of farm animals, protection of the host from intestinal infections, alleviation of lactose intolerance, relief of constipation, anticarcinogenic, anticholesterolaemic and immunostimulatory effects, nutrient synthesis and bioavailability, prevention of genital and urinary tract infections. This paper reviews the potential of LAB used in several fermented food production systems and their importance (probiotic role, nutrient synthesis, immunostimulatory effect, flavour production, food protection due to bacteriocin and acid production) in human nutrition.

Keywords: bacteriocin, cereal, fermentation, fermented products, organic acids, probiotics

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INTRODUCTION

Lactic acid bacteria (LAB) have been used to ferment or culture foods for at least 4000 years. Fermented foods make up an important contribution to the human diet in many countries throughout the world; fermentation is technology which preserves food, improves its nutritional value and enhances its sensory properties (Murth and Kumar 1995; Steinkraus 1996).

Fermentation is a process dependent on the biological activity of microorganisms for production of a range of metabolites which can suppress the growth and survival of undesirable microflora in foodstuffs (Klaenhammer 1993; Soomro *et al*. 2002).

The most single important development permitting the formation of civilization was the ability to produce and store large quantities of food. It is beneficial to be able to store as much food as possible in order to minimize the amount of time spent gathering that food. Food fermentation has great economic value and it has been accepted that these products contribute in improving human health.

Preservation of food and beverages resulting from fermentation has been an effective form of extending the shelf-life of foods for millennia.

Alcoholic fermentations involved in wine-making and brewing are thought to have been developed during the period 2000-4000 BC by the Egyptians and Sumerians. The Egyptians also developed dough fermentations used in the production of leavened bread (Desrosier 1977).

There are many examples which report on the inhibition

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of spoilage and pathogenic bacteria by LAB (Price and Lee 1970; Klaenhammer 1993).

A group of bacteria know collectively as LAB is primarily responsible for many of the microbial transformations found in the more common fermented food products: genera including *Lactococcus*, *Lactobacillus*, *Enterococcus*, *Streptococcus*, *Leuconostoc*, and *Pediococcus* generally produce lactic acid as their major end product. They are strictly fermentative and lack the ability to synthesize haeme which means that they are consequently catalase negative and lack a terminal electron transport chain (Condon 1987).

Several traditional fermented products have been documented in different African countries and include non-alcoholic beverages, alcoholic beverages, breads, pancakes, porridges cheeses and milks (Van der walt 1956; Haggblade and Holzapfel 1989; Ashenafi 1990; Gorbach 1990; Dirar 1993; Mzestigye and Okurut 1995; Steinkraus 1996; Gorbach 2000; Savadogo *et al*. 2004)

LAB is of interest since it promotes good health in animals and man (Gorbach 1990, 2000). Also LAB can be use as probiotics (Fuller 1989). Fuller (1989) defined a probiotic as a live microbial feed supplement beneficial to the host (man or animal) by improving the microbial balance within its body. Some of the positive effects of probiotics are: growth promotion of farm animals (Havenaar and Huis in't Veld 1992), protection of hosts from intestinal infections (de Simone 1986; Fuller 1989; O'Sullivan *et al.* 1992), alleviation of lactose intolerance (Fuller 1989; Marteau *et al.* 1990; Sawada *et al.* 1990), relief of constipation (Oyetayo and Oyetayo 2005), anticarcinogenic effect (O'Sullivan *et al.* 1992; Isolauri 2004; Lee *et al*. 2004; Saikali *et al*. 2004; Oyetayo and Oyetayo 2005), antichloesterolaemic effects (Tamine 2002; Oyetayo and Oyetayo 2005; Parvez *et al.* 2005), nutrient synthesis and bioavailabiliy (Oyetayo and Oyetayo 2005), prevention of genital and urinary tract infection (McLean and Rosenstein 2000) and immunostimulatory effects (Perdigon and Alvarez 1992; Malin *et al.* 1997; MacFarlane and Cummings 2002; McNaught *et al.* 2005).

Fermented food may have a potential for use as weaning foods if they promote organic acids such as lactic, acetic and propionic acids, produced during the fermentation process of cereal foods, and which are inhibitory of many diarrhoea-causing bacteria (Simango and Rukure 1992). Fermented foods contribute to about one third of the diet worldwide (Campbell-Platt 1994). The content and quality of cereal proteins may be improved by fermentation (Wang and Fields 1978; Cahvan *et al*. 1988). Natural fermentation of cerals increases their relative nutritive value and available lysine (Hamad and Fields 1979). Bacterial fermentations involving proteolytic activity are expected to increase the biological availability of essential amino acids more so than yeast fermentation which mainly degrade carbohydrate (Chaven and Kadam 1989).

This article reviews the potential of lactic acid bacteria using to obtained several fermented food and their importance (probiotic, immunostimulatory, flavour, food protecttor) in human nutrition.

WHAT ARE LACTIC ACID BACTERIA?

Definiton

Lactic acid bacteria are a group of related bacteria that produce lactic acid as a result of carbohydrate fermentation.

These organisms are heterotrophic and generally have complex nutritional requirements because they lack many biosynthetic capabilities. Most species have multiple requirements for amino acids and vitamins. Because of this, lactic acid bacteria are generally abundant only in communities where these requirements can be provided. They are often associated with animal oral cavities and intestines (e.g. *Enterococcus faecalis*), and plant leaves (*Lactobacillus*, *Leuconostoc*).

LAB are generally described as Gram positive, non-sporing cocci or rods with lactic acid as the major product of carbohydrate fermentation.

LAB refers to a large group of beneficial bacteria that have similar properties and all produce lactic acid as and product of the fermentation process. Traditionally LAB comprise four genera *Lactobacillus*, *Leuconostoc*, *Pediococcus* and *Streptococcus*. However, several new genera have been suggested for inclusion in the group of LAB due to a recent taxonomic revision (Axelson; 1998). The genus *Streptococcus* has been reorganized into *Enterococcus*, *Lactococcus*, *Streptococcus* and *Vagococcus* (Axelson 1998).

They are widespread in nature and are also found in our digestive systems.

LAB are all gram positive, anaerobic, microaerophilic or aero-tolerant; catalase negative; rods or cocci; most importantly they produce lactic acid as the sole major or an important product from the energy-yielding fermentation of sugars. It used to be thought that all LAB were non motile and non-sporing; although there are now the sporolactobacilli and motile organisms which are reported to otherwise fit with the LAB. They are chemo-organotrophic and grow only in complex media. Fermentable carbohydrates are used as energy source (Campbell-Platt 1994).

Phylogenetic relatioships

Phylogenetic relationships of LAB based on 16 S and 23 S rRNA sequence data divide the Gram positive bacteria form into two lines of descent. One phylum consists of Gram positive bacteria with a DNA base composition of less than 50 mol % guanine plus cytosine (G+C), the so-called *Clostridium* branch, whereas the other branch (*Actinomycetes*) comprises organisms with a G+C content that is higher than 50 mol %. The typical LAB, such as *Carnobacterium*, *Lactobacillus*, *Lactococcus*, *Leuconostoc*, *Pediococcus* and *Streptococcus*, have a G+C content of less than 50 mol % and belong to the *Clostridium* branch.

FERMENTATION FUNCTIONS IN FOODS

LAB are able to produce a large variety of components which contribute to the flavour, colour, texture and consistency of fermented foods (**Tables 1, 2, 3**).

According to Steinkraus (1995) traditional fermentation of foods (cereal, milk, fruits) serves several functions: a) Enrichment of the diet through development of a diversity of flavours, aromas and textures in food substrates; b) Preservation of substantial amounts of food through lactic acid, alcoholic, acetic acid and alkaline fermentations; c) Enrichment of food substrates biologically with protein essential amino acids essential fatty acids vitamins; d) Detoxification in cooking times and fuel requirements microbial activity in foods makes them more attractive in terms of appearance and flavours. Such foods are more appetizing and easily digestible. Fermentation improves the digestibility of the ingredients for human consumption and enhances the keeping quality and shelf life.

CEREAL-BASED FERMENTED PRODUCTS (TABLE 1)

Cereals are one of the oldest of all cultivated plants. Today, there are more than 5000 cultivars of wheat in existence and as a result wheat can be grown in a relatively wide range of climatic conditions. Cereal grains are the fruit of plants belonging to the grass family *Poaceae*. Cereals have a variety of uses as food. Only two cereals, wheat and rye, are suited to the preparation of leavened bread. The most general usage of cereals is in cooking, either directly in the form of grain, flour, starch, or as semolina. Another common usage of cereals is in the preparation of alcoholic drinks such as whiskey and beer, vodka, American bourbon, Japanese sake etc. A variety of unique indigenous fermented foods, other than leavened bread and alcoholic beverages are also pro-

Table1 Some important indigenous fermented cereal products around the world (based on and modified from Soni and Sandhu 1999).

Fermented food name	Country/place	Ingredient(s)	Nature of product	Product use
Ang-Kak (Chinese red rice)	China, Taiwan, Philippines, Thailand	Rice	Solid	Colouring other foods
Ambali	India	Millet flour	Semi-solid	All time food
Bhatura	India North	White wheat flour	Deep fried; bread	Breakfast
Fermented rice	India	Rice	Semi-solid	Breakfast
Hopper (*Appa*)	Sri Lanka	Rice or White wheat flour and cocconut water	Semi-solid	Breakfast
Jalebie	India, Pakistan	White wheat flour	Deep fried; crispy pretzel	Confection food
Kenkey	Ghana	Maize	Semi-solid	Breakfast, lunch and supplement to fish stews
Kisra	Sudan	Sorghum flour	Spongy bread	Staple food
Kulcha	India (North), Pakistan	White wheat flour	Flat bread	Staple food
Mahewu	South Africa	Maize meal	Liquid	Beverage food
Nan	India (North) Pakistan, Iran, Afghanistan	White wheat flour	Flat bread	Staple food
Ogi	Nigeria	Maize, Millet or Sorghum	Semi-solid	Breakfast and infant food
Pozol	Mexico	White maize	Liquid	Beverage or Porridge
Puto	Philippines	Rice	Semi-solid	Breakfast and snack food
Shamsy bread	Egypt	Flour	Spongy bread	Staple food
Uji	Kenya, Uganda, Tanzania	Maize, sorghum or millet flour	Semi-solid	Breakfast and lunch

Table 2 Some important indigenous fermented legume products around the world (based on and modified from Soni and Sandhu 1999).

Fermented food name	Country/place	Ingredient(s)	Nature of product	Product use
Bhallae	India	Black gram	Deep fried patties	Snack after soaking in curd, water
Chee-fan	China	Soybean, whey curd	Solid	Eaten fresh, cheese-like
Dawadawa	West Africa, Nigeria	African locust bean	Solid	Eaten fresh, supplement to soups, stews
Khaman	Western India	Bengal gram	Spongy cake	Breakfast food
Kenima	Nepal, Sikkim, Darjeeling, District of West Bengal in India	Soybeans	Solid	Snack
Ketjap	Indonesia	Black soybeans	Syrup	Seasoning agent
Meitauza	China, Taiwan	Soybean cake	Solid	Fried in oil or cooked with vegetables
Meju	Korea	Soybeans	Paste	Seasoning agent
Miso	Japan, China	Soybeans/soybeans and rice	Paste	Soup base, seasoning agent
Natto	Northern Japan	Soybeans	Solid	Roasted or fried in oil used as a meat substitute
Oncom	Indonesia	Peanut press cake	Solid	Roasted or fried in oil used as a meat substitute
Papadam	India	Black gram and spices	Circular tortilla like wafers	Condiment
Soybean milk	China, Japan	Soybeans	Liquid	Drink
Sufu	China, Taiwan	Soybean, whey curd	Solid	Soybean cheese, condiment
Soy sauce	Japan, China, Philippines	Soybeans/soybeans and wheat	Liquid fish, cereals and vegetables	Seasoning agent for meat
Tempeh	Indonesia and its vicinity	Soybeans	Solid	Fried in oil, roasted or used as meat substitute in soup
Vadai	India	Black gram	Deep fried pattles	Snack
Warries	Northern India	Black gram and spices	Ball like, hollow, brittle	Spicy condiment eaten with vegetables, legumes, rice

Table 3 Some important indigenous fermented legume-cereal products around the world (based on and modified from Soni and Sandhu 1999).

Fermented food name	Country/place	Ingredient(s)	Nature of product	Product use
Dhokia	Western India	Rice, Bengal gram	Spongy cake	Condiment
Dosa	Southern India	Rice, black gram	Spongy, pancake	Condiment
Hama natto	Japan	Wheat flour, whole soybeans	Raisin-like, soft	Flavouring agent for meat and fish, eaten as snack
Idli	Southern India	Rice, black gram	Spongy	Breakfast food
Kecap	Indonesia and vicinity	Wheat, soybeans	Liquid	Condiment, seasoning agent
Tao-si	Philippines	Wheat flour, soybeans	Semi-solid	Seasonig agent
Taotjo	East Indies	Roasted wheat, Meal or glutinous rice, soybeans	Semi-solid	Condiment

duced in regions of the word that rely mainly on plant sources of protein and and calories.

Fermented food contribute to about one third of the diet worldwide (Campbell-Platt 1994). Cereals are particulary important substrates for fermented foods all over the world and are staples in the Indian subcontinent in Asia and in Africa. Fermentation causes changes in food quality indices including texture, flavor, appearance, nutrition and safety. Natural fermentation of cereals increases their relative nutritive value and available lysine (Hamad and Fields 1979).

Fermentation is especially important in the developing world because it is inexpensive and is a simple method of improving the nutritional and organoleptic qualities of otherwise monotonous cereal products (Hesseltine 1983; Cooke *et al*. 1987; Chavan and Kadam 1989). It does not require expensive equipment or special expertise and can be achieved in a very short period of time (Lay and Fields 1981). In high temperature and humid regions such as Africa, where cooling facilities are not readily available, fermentation provides a cheap but effective form of food preservation (Hesseltine and Wang 1979; Umoh and Field 1981; Chavan and Kadam 1989).

In Africa most fermented foods are based on cereals. Most of these fermentations are spontaneous, and involve LAB, yeasts or a mixture of these as the functional microorganisms. A wide range of cereal-based fermented foods exists such as *mawè* in Benin (Hounhouigan *et al.* 1991), *kenkey* in Ghana, *poto-poto* in Congo (Blandino *et al.* 2003), *ogi* and *kwunu-zaki* in Nigeria (Oyewole 1997), *injera* in Ethiopia, *uji* and *togwa* in Tanzania, *kisra* in Sudan (Tomkins *et al.* 1988).

Ogi

Porridge prepared from fermented maize, sorghum or millet in West Africa. Microbiological and nutritional studies of *ogi* (Odunfa 1985) showed that the LAB *Lb plantarum*, aerobic bacteria *Corynebacterium* and *Aerobacter*, the yeasts *Candida mycoderma*, *Saccharomyces cerevisiae* and *Rhodotorula* and moulds *Cephalosporium*, *Fusarium*, *Aspergillus* and *Penicillium* are the major organisms responsible for the fermentation and nutritional improvement of *ogi*. Odunfa (1985) determined that *Lb plantarum* was the predominant organism in the fermentation responsible for lactic acid production.

Traditional preparation of *ogi* involves soaking of corn kernels in water for 1 to 3 days followed by wet milling and sieving to remove bran, hulls and germ. The pomace is retained on the sieve and later discarded as animal feed while the filtrate is fermented (for 2 to 3 days) to yield *ogi*, which is a sour, white, starchy sediment.

Tempe kedele

A fermented product of Indonesia which is prepared by incubating the soaked soybeans in a warm place, and is are knitted into a compact cake by a fibrous mould mycelium for 1 to 3 days (Hesseltine 1965). *Tempe kedele* is a white, mould-covered cake produced by fungal fermentation of dehulled, hydrated, and partially cooked soybean cotyledons.

The essential steps in the production of *tempe* are: cleaning the soybeans, hydratation and acid fermentation, dehulling dry or following hydratation, partial cooking, draining, cooling, surface drying, placing the soybean cotyledons in suitable fermentation containers, inoculating with *tempe* mould (*Aspergillus niger*, *Mucor javenicus*, *Mucor roxii*, *Rhizopus achlamydosporus*), incubating until the cotyledons are completely covered with mould mycelium, harvesting and selling, cooking for consumption.

Traditionally, the inoculated cotyledons are then wrapped in small packets using wilted banana or other large leaves and are incubated in a warm place for two or three days.

Natto, tu-si, tao-si, tnua-nao

Fermented whole soybeans are known as *natto* in Japan, *tu-si* in China, *tao-si* in The Phillipines and *tnua-nao* in Thailand (Hesseltine and Wang 1979; Reddy *et al*. 1982).

Natto is a Japanese original and traditional food. *Natto* is a fermented food made of soybeans and is rich in vegetable protein (**Table 2**).

Kenkey

Kenkey is a fermented maize dough which is consumed in Ghana. During the production of Kenkey dough is divided into two parts: one part “the aflata” is cooked into a thick porridge, while the other uncooked part is later mixed with “aflata”. The resulting mixture is moulded into balls and wrapped in dried maize husk or plantain leaves, after which it is steamed. Dough is fermented for 72 hours. Microbial studies of *kenkey* production by Jespersen *et al*. (1994) highlighted the significance of yeasts and moulds in the production of this fermented maize dough. A mixed flora consisting of *Candida*, *Saccharomyces*, *Penicillium*, *Aspergillus* and *Fusarium* species were found to be the dominance microorganisms during the preparation of this food product. Halm *et al*. (1993) concluded that a homogenous group of obligatively heterofermentation lactobacilli related to *Lactobacillus fermentum* and *Lactobacillus reuteri* play a dominant role during *kenkey* production (**Table 1**).

LAB AS PROBIOTICS

Definiton

The term "probiotic" has been given many meanings, but it now generally recognized as a fermented dairy product containing live LAB that have been specially selected to provide specific health benefits (Fuller 1989). Most probiotic products contain bacteria from the genera *Lactobacillus* or *Bifidobacterium*. Probiotic products should be safe, effecttive, and should maintain their effectiveness and potency until they are consumed (Schrezenmeir and de Vrese 2001).

Probiotics are usually defined as microbial food supplements with beneficial effects on the consumers. Recent scientific investigation has supported the important role of probiotics as a part of a healthy diet for human as well as for animals and may be an avenue to provide a safe, cost-effecttive, and natural approach that adds a barrier against microbial infection.

Functions of probiotics

Reported functions of probiotics as a part of a healthy diet include: a) Providing support to the immune system (Malin *et al*.1997; MacFarlane and Cummings 2002; McNaught *et al*. 2005); b) Maintaining a healthy gut flora to provide increased resistance to disease (Naidu *et al*. 1999; Parvez *et al*. 2006); c) Reducing lactose intolerance (Fernandes *et al*. 1987; Marteau *et al*. 1990); d) May assist in preventing some cancers (Reddy *et al*. 1973; Isolauri 2004; Lee *et al*. 2004; Saikali *et al*. 2004); e) May reduce cholesterol for some individuals (Lin *et al*. 1989; Taranto *et al*. 1998).

The roles of probiotic bacteria in dairy fermentations is to assist in: a) the preservation of milk by the generation of lactic acid and possibly antimicrobial compounds (Parvez *et al*. 2006); b) the production of flavour compounds (e.g., acetaldehyde in yoghurt and cheese) and other metabolites (e.g., extracellular polysaccharides) that will provide a product with the organoleptic properties desired by the consumer (Parvez *et al*. 2006); c) to improve the nutritional value of food, as in, for example, the release of free amino acids or the synthesis of vitamins (Parvez *et al*. 2006); d) the provision of special therapeutic or prophylactic properties (Reddy *et al*. 1973; Fernandes *et al*. 1987; Gilliland 1990; O’Sullivan *et al*. 1992) and control of serum cholestrol levels (Lin *et al*. 1989).

For centuries folklore has suggested that fermented dairy products containing probiotic cultures are healthful. Recent controlled scientific investigation has supported some of these traditional views, suggesting the value of probiotics as part of a healthy diet. The ability of probiotic bacteria to support the immune system could be important to elderly or other people with a compromised immune function (Oyetayo and Oyetayo 2005).

ANTIMICROBIAL COMPOUNDS PRODUCED BY LAB

Bacteriocin classification

LAB involved in the fermentation of a range of milk, meat, cereal and vegetable foods (Mckay and Baldwin 1990; Goldberg and Williams 1991). The antimicrobial compounds produced by LAB, the bacteriocins, can inhibit the growth of pathogenic bacteria which possibly contaminants in the fermented products (Raccah *et al*. 1979; Smith and Palumbo 1983; Cintas *et al*. 1998).

Bacteriocins can be divided into three main groups as follows, based on the groupings proposed by Klaenhammer (1993):

- Class I: the lantibiotic family; these are generally small bacteriocins composed of one or two peptides of approximately 3 kDA. An unusual feature of this group is that they are post-translationally modified to contain lanthionine β-methyllanthionine and dehydrated amino acids, while at least two members of the group also contain D-alanine (Skaugen *et al*. 1994; Rayan *et al*. 1999).
- Class II: small non-modified peptides; these are generally small unmodified of <5kDa, which are subdivided into two groups. The first (class IIa) are the *Listeria*-active peptides which are characterized by a YGNGU N-terminus. As in the lantibiotic family, some class II bacteriocins are composed of two separate peptides and are refered to as the classIIb type. The two component non-modified bacteriocins include lacticin F (Muriana and Klaenhamer 1991) and lactococcin G (Nissen-Meyer *et al*. 1992).
- Class III: large heat-labile proteins, this class III bacteriocins are the least well-characterized group and consist of heat-labile proteins which are generally >30kDa.

Organic acids

The levels and types of organic acids produced during the fermentation process depend on the species of organisms, culture composition and growth conditions (Lindgren and Dobrogosz 1990). The antimicrobial effect of organic acids lies in the reduction of pH, as well as the undissociated form of the molecules (Gould 1991; Podolak *et al*. 1996). Acids are generally throught to exert their antimicrobial effect by interfering with the maintenance of cell membrane potential, inhibiting active transport, reducing intracellular pH and inhibiting a variety of metabolic function (Doores 1993). They have a very broad mode action and inhibit both Gram-positive and Gram-negative bacteria as well as yeast and moulds (Blom and Mortved 1991; Caplice and Fitzgerald 1999).

Lactic acid is the major metabolite of LAB fermentation. At a low pH, a large amount of lactic acid is in the undissociated form, and it is toxic to many bacteria, fungi and yeasts.

Acetic and propionic acids produced by LAB strains interact with cell membranes and cause intracellular acidification and protein denaturation (Huang *et al*. 1986). Acetic and propionic acids are more antimicrobially effective than lactic acid due to their pH higher value (lactic acid 3.08; acetic acid 4.75; propionic acid 4.87).

Hydrogen peroxide and carbon dioxide

The antimicrobial effect of hydrogen peroxide (H_2O_2) may result from the peroxidation of membrane lipids thus the increased membrane permeability (Kong and Davison 1980).

Carbon dioxide plays a role in creating an anaerobic environment which inhibits enzymatic decarboxylations, and accumulation of CO_2 in the membrane lipid bilayer may cause a dysfunction in permeability (Eklund 1984).

CONCLUSION

Traditional fermentations are likely to remain an important part of the global food supply; many may evolve into fermentations involving the use of starter cultures, enzyme additives and controlled environmental conditions, and others may benefit.

Dairy foods fermented by LAB have long been held in special favor as safe and nutritious foods that may also elicit positive effects on health and well being. There is increasing evidence the live LAB in these products do indeed have health benefits. Select members of the LAB have now been implicated through clinical studies to provide resistance to enteric pathogens, stimulate the immune system, and help maintain a balanced gastrointestinal micro-flora.

Some advantages of traditional fermentations are that they are labor-intensive, integrated into village life, familiar, utilize locally produced raw materials, inexpensive, have barter potential and the subtle variations resulting, add interest and tradition to local consumers. From this perspective, research leading to new fermentation technologies should be sensitive to social and economic factors in developing countries. Rapid displacement of traditional foodstuffs in developing countries with technologies developed in more affluent countries may result in centralised production, distribution problems, less local involvement in food processing, less employment in some areas, less nutritionally adequate substitutions in raw materials, displacement of traditional arts, loss of unique local know-how, dependence on importation of equipment and materials, initially require the use of outside consultants, and may otherwise not meet local needs as fully as traditional fermented products.

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