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Review

Cereal-based fermented foods and beverages

A. Blandino[b], M.E. Al-Aseeri[a], S.S. Pandiella[a,*], D. Cantero[b], C. Webb[a]

[a]Satake Centre for Grain Process Engineering, UMIST, Department of Chemical Engineering, PO Box 88, Manchester M60 QD, UK
[b]Department of Chemical Engineering, Faculty of Sciences, University of Cádiz, Polígono Río San Pedro, Puerto Real, 11510, Cadiz, Spain

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Abstract

Cereal grains constitute a major source of dietary nutrients all over the world. Although cereals are deficient in some basic components (e.g. essential aminoacids), fermentation may be the most simple and economical way of improving their nutritional value, sensory properties, and functional qualities. This review focuses first on some of the indigenous fermented foods and beverages produced world-wide that have not received the scientific attention they deserve in the last decades. Products produced from different cereal substrates (sometimes mixed with other pulses) fermented by lactic acid bacteria, yeast and/or fungi are included. Finally, newly developed cereal-based foods with enhanced health properties will also be reviewed.

Keywords: Cereals; Fermented foods; Fermented beverages; Lactic acid bacteria; Yeast; Fungi

Contents

* Corresponding author. Tel.: +44-161-200-4429; fax +44-161-200-4399.
E-mail address: s.pandiella@umist.ac.uk (S.S. Pandiella).

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1. Introduction

Since the beginning of human civilisation there has been an intimate companionship between the human being, his fare and the fermentative activities of microorganisms. These fermentative activities have been utilised in the production of fermented foods and beverages, which are defined as those products that have been subordinated to the effect of microorganisms or enzymes to cause desirable biochemical changes. The microorganisms responsible for the fermentation may be the microflora indigenously present on the substrate, or they may be added as starter cultures (Harlander, 1992).

Fermentation is one of the oldest and most economical methods of producing and preserving food (Billings, 1998; Chavan & Kadam, 1989). In addition, fermentation provides a natural way to reduce the volume of the material to be transported, to destroy undesirable components, to enhance the nutritive value and appearance of the food, to reduce the energy required for cooking and to make a safer product (Simango, 1997).

Since the dawn of civilisation, methods for the fermentation of milks, meats, vegetables and cereals have been described. The earliest records appear in the Fertile Crescent (Middle East) and date back to 6000 BC. Of course, the preparation of these fermented foods and beverages was in an artisan way and without any knowledge of the role of the microorganisms involved. However, by the middle of the nineteenth century, two events changed the way in which food fermentations were performed and the understanding of the process. Firstly, the industrial revolution resulted in the concentration of large masses of populations in towns and cities. As a consequence, food had to be made in large quantities, requiring the industrialisation of the manufacturing process. In the second place, the blossoming of Microbiology as a science in the 1850s formed the biological basis of fermentation, and the process was understood for the first time (Caplice & Fitzgerald, 1999). Ever since, the technologies for the industrial production of fermented products from milk, meat, fruits, vegetables and cereals are well developed and scientific work is actively carried out all over the world (Hirahara, 1998; Pagni, 1998).

Fermented foods are produced world-wide using various manufacturing techniques, raw materials and microorganisms. However, there are only four main fermentation processes: alcoholic, lactic acid, acetic acid and alkali fermentation (Soni & Sandhu, 1990). Alcohol fermentation results in the production of ethanol, and yeasts are the predominant organisms (e.g. wines and beers). Lactic acid fermentation (e.g. fermented milks and cereals) is mainly carried out by lactic acid bacteria. A second group of bacteria of importance in food fermentations are the acetic acid producers from the *Acetobacter* species. *Acetobacter* convert alcohol to acetic acid in the presence of excess oxygen. Alkali fermentation often takes place during the fermentation of fish and seeds, popularly used as condiment (McKay & Baldwin, 1990).

The preparation of many indigenous or traditional fermented foods and beverages remains today as a house art. They are produced in homes, villages and small-scale industries. On the contrary, the preparation of others, such as soy sauce, has evolved to a biotechnological state and is carried out on a large commercial scale (Bol & de Vos, 1997). In the distant past, there was no verified data on the economic, nutritional, technical and quality control implications of the indigenous fermented food. However, in the last 20 years, the number of books and articles dealing with indigenous fermented beverages and foods found around the whole world have rapidly increased (Steinkraus, Ayres, Olek, & Farr, 1993). In this context, this review aims to list and summarize the production processes of some of the most common traditional cereal-based fermented foods. In addition some of the microbiological and nutritional properties of those foods and the technological improvements which have been achieved on its production will be highlighted. Some cereal-based fermented products recently developed will also be reviewed.

2. Biochemical changes during cereal fermentation

Cereal grains are considered to be one of the most important sources of dietary proteins, carbohydrates, vitamins, minerals and fibre for people all over the world. However, the nutritional quality of cereals and the sensorial properties of their products are sometimes inferior or poor in comparison with milk and milk products. The reasons behind this are the lower protein content, the deficiency of certain essential amino acids (lysine), the low starch availability, the presence of determined antinutrients (phytic acid, tannins and polyphenols) and the coarse nature of the grains (Chavan & Kadam, 1989).

A number of methods have been employed with the aim of ameliorate the nutritional qualities of cereals. These include genetic improvement and amino acid supplementation with protein concentrates or other protein-rich sources such as grain legumes or defatted oil seed meals of cereals. Additionally, several processing technologies which include cooking, sprouting, milling and fermentation, have been put into practise to improve the nutritional properties of cereals, although probably the best one is fermentation (Mattila-Sandholm, 1998). In general, natural fermentation of cereals leads to a decrease in the level of carbohydrates as well as some non-digestible poly and oligosaccharides. Certain amino acids may be synthesised and the availability of B group vitamins may be improved. Fermentation also provides optimum pH conditions for enzymatic degradation of phytate which is present in cereals in the form of complexes with polivalent cations such as iron, zinc, calcium, magnesium and proteins. Such a reduction in phytate may increase the amount of soluble iron, zinc and calcium several folds (Chavan & Kadam, 1989; Gillooly et al., 1984; Haard et al., 1999; Khetarpaul & Chauhan, 1990; Nout & Motarjemi, 1997; Stewart & Getachew, 1962).

The effect of fermentation on the protein and amino acids levels is a topic of controversy. For example, during the fermentation of corn meal the concentrations of available lysine, methionine, and tryptophan increase (Nanson & Field, 1984). In the same way, fermentation significantly improves the protein quality as well as the level of lysine in maise, millet, sorghum, and other cereals (Hamad & Fields, 1979). On the contrary, investigations of the nutritive value of sorghum kisra bread showed no increase in the lysine content, although tyrosine and methionine levels did increase (McKay & Baldwin, 1990). In the same line, it has been reported that the tryptophan content increases during uji manufacture while a significant drop in lysine content was measured (McKay & Baldwin, 1990). It appears that the effect of fermentation on the nutritive value of foods is variable, although the evidence for improvements is substantial.

Fermentation also leads to a general improvement in the shelf life, texture, taste and aroma of the final product. During cereal fermentations several volatile compounds are formed, which contribute to a complex blend of flavours in the products (Chavan & Kadam, 1989). The presence of aromas representative of diacetyl acetic acid and butyric acid make fermented cereal-based products more appetizing (see Table 1).

Traditional fermented foods prepared from most common types of cereals (such as rice, wheat, corn or sorghum) are well known in many parts of the world. Some are utilized as colorants, spices, beverages and breakfast or light meal foods, while a few of them are used as main foods in the diet. The microbiology of many of these products is quite complex and not known. In most of these products the fermentation is natural and involves mixed cultures of yeasts, bacteria and fungi. Some microorganisms may participate in parallel, while others act in a sequential manner with a changing dominant flora during the course of the fermentation. The common fermenting bacteria are species of *Leuconostoc, Lactobacillus, Streptococcus, Pediococcus, Micrococcus* and *Bacillus*. The fungi genera *spergillus*, *Paecilomyces, Cladosporium*, *Fusarium, Penicillium* and *Trichothecium* are the most frequently found in certain products. The common fermenting yeasts are species of *Saccharomyces*, which results in alcoholic fermentation (Steinkraus, 1998).

The type of bacterial flora developed in each fermented food depends on the water activity, pH, salt concentration, temperature and the composition of the food matrix. Most fermented foods, including the major products that are common in the western world, as well of many of those form other sources that are less well characterised, are dependent on lactic acid bacteria (LAB) to mediate the fermentation process (Conway, 1996). Lactic acid fermentation contributes towards the safety, nutritional value, shelf life and acceptability of a wide range of cereal based foods (Oyewole, 1997). In many of those processes, cereal grains, after cleaning, are soaked in water for a few days during which a succession of naturally occurring microorganisms will result in a population dominated by LAB. In such fermentations endogenous grain amylases generate fermentable sugars that serve as a source of energy for the lactic acid bacteria. Fermentation is often just one step in the process of fermented food preparation. Other operations such as sise reduction, salting or heating also affect the final product properties (Nout & Motarjemi, 1997).

Table 1
Compounds formed during cereal fermentation (Campbell-Platt, 1994)

Organic acids		Alcohols	Aldehydes and ketones	Carbonyl compounds
Butyric	Heptanoic	Ethanol	Acetaldehyde	Furfural
Succinic	Isovaleric	*n*-Propanol	Formaldehyde	Methional
Formic	Propionic	Isobutanol	Isovaleraldehyde	Glyoxal
Valeric	*n*-Butyric	Amy alcohol	*n*-Valderaldehyde	3-Methyl butanal
Caproic	Isobutyric	Isoamyl alcohol	2-Methyl butanol	2-Methyl Butanal
Lactic	Caprylic	2,3-Butanediol	*n*-Hexaldehyde	Hydroxymethyl furfural
Acetic	Isocaproic	β-Phenylethyl alcohol	Acetone	
Capric	Pleargonic		Propionaldehyde	
Pyruvic	Levulinic		Isobutyraldehyde	
Plamitic	Myristic		Methyl ethyl ketone	
Crotonic	Hydrocinnamic		2-Butanone	
Itaconic	Benzylic		Diacetyl	
Lauric			Acetoin	

According to Aguirre and Collins (1993), the term LAB is used to describe a broad group of Gram-positive, catalase-negative, non-sporing rods and cocci, usually non-motile, that utilize carbohydrates fermentatively and form lactic acid as the major end product (see Table 2). According to the pathways by which hexoses are metabolised they are divided into two groups: homofermentative and heterofermentative. Homofermentative such as *Pediococcus, Streptococcus, Lactococcus* and some *Lactobacilli* produce lactic acid as the major or sole end product of glucose fermentation. Heterofermenters such as *Weisella* and *Leuconostoc* and some *Lactobacilli* produce equimolar amounts of lactate, CO_2 and ethanol from glucose (Aguirre & Collins, 1993; Tamime & O'Connor, 1995).

The preservative role of lactic fermentation technology has been confirmed in some cereal products. The antibiosis mediated by LAB has been attributed to the production of acids, hydrogen peroxide and antibiotics.

Table 2
Genera of lactic acid bacteria involved in cereal fermentations (McKay & Baldwin, 1990; Oberman & Libudzisz, 1996; Suskovic, Kos, Matosic, & Maric, 1997)

Genera of LAB	Cell form	Catal.	Gram (±)
Lactobacillus	Rods (Bacilli; coccobacilli)	–	+
Streptococcus	Spheres in chains (Cocci)	–	+
Pediococcus	Spheres in tetrads (Cocci)	–	+
Lactococcus	Cocci	–	+
Leuconostoc	Spheres in chains (Cocci)	–	+
Bifidobacterium	Branched rods	–	+
Carnobacterium	Cocci	–	+
Enterococcus	Cocci	–	+
Sporolactobacillus	Rod	–	+
Lactosphaera	Cocci	–	+
Oenococcus	Cocci	–	+
Vagococcus	Cocci	–	+
Aerococcus	Cocci	–	+
Weissella	Cocci	–	+

The production of organic acids reduces the pH to below 4.0 making it difficult for some spoilage organisms that are present in cereals to survive (Daly, 1991; Oyewole, 1997). The antimicrobial effect is believed to result from the action of the acids in the bacterial cytoplasmatic membrane, which interferes with the maintenance of the membrane potential and inhibits the active transport. Apart from their ability to produce organic acids, the LAB posses the ability to produce hydrogen peroxide through the oxidation of reduced nicotin-amide adenine dinucleotide (NADH) by flavin nucleotides, which react rapidly with oxygen. As LAB lack true catalase to break down the hydrogen peroxide generated, it can accumulate and be inhibitory to some microorganisms (Caplice & Fitzgerald, 1999). On the other hand, tannin levels may be reduced as a result of lactic acid fermentation, leading to increased absorption of iron, except in some high tannin cereals, where little of no improvement in iron availability has been observed (Nout & Motarjemi, 1997). Another advantage of lactic acid fermentation is that fermented products involving LAB have viricidal (Esser, Lund, & Clemensen, 1983) and antitumour effects (Oberman & Libudzisz, 1996; Seo et al., 1996).

A range of indigenous fermented foods prepared from cereals in different parts of the world are listed in Table 3. It can be observed from this table that most of those products are produced in Africa and Asia and a number of them utilize cereals in combination with legumes, thus improving the overall protein quality of the fermented product. Cereals are deficient in lysine, but are rich in cysteine and methionine. Legumes, on the other hand, are rich in lysine but deficient in sulphur containing amino acids. Thus, by combining cereal with legumes, the overall protein quality is improved (Campbell-Platt, 1994). Some of these cereal-based fermented products, classified according to the main raw constituent will be described in the following sections.

Table 3
Most common indigenous cereal and cereal–legume-based fermented foods and beverages (Adams, 1998; Chavan & Kadam, 1989; Harlander, 1992; Sankaran, 1998; Soni & Sandhu, 1990)

Product	Substrates	Microorganisms	Nature of use	Regions
Adai	Cereal/legume	*Pediococcus, Streptococcus, Leuconostoc*	Breakfast or snack food	India
Anarshe	Rice	LAB	Breakfast, sweetened snack food	India
Ang-kak (anka, red rice)	Rice	*Monascus purpureus*	Dry red powder as colorant	China, Southeast Asia, Syria
Atole	Maise	LAB	Porridge based on maise dough	Southern Mexico
Bagni	Millet	Unknown	Liquid drink	Caucasus
Banku	Maise, or maise and cassava	LAB, moulds	Dough as staple	Ghana
Bhattejaanr	Rice	*Hansenula anomala, Mucor rouxianus*	Sweet sour alcoholic paste	India, Sikkim
Bogobe	Sorghum	Unknown	Soft porridge staple	Botswana
Bouza	Wheat	Unknown	Thick, acidic, yellow, alcoholic beverage	Egypt
Boza	Wheat, millet, maise and other cereals	*Lactobacillus, Saccharomyces cerevisiae*, *Leuconostoc*	Thick, sweet, slightly sour beverage	Albania, Turkey, Bulgaria, Romania
Braga	Millet	Unknown	Liquid drink	Romania
Brem	Rice	Unknown	Cake	Indonesia
Brembali	Rice	*Mucor indicus, Candida*	Dark brown alcoholic drink	Indonesia
Burukutu	Sorghum	*Saccharomyces cerevisiae, S. chavelieri, Leuconostoc mesenteroides*, *Candida*, *Acetobacter*	Alcoholic beverage of vinegar-like flavour	Nigeria, Benin, Ghana
Busa	Rice or millet	*Lactobacillu*s, *Saccharomyces*	Liquid drink	Syria, Egypt, Turkestan
Busaa	Maise	*Lactobacillus helveticus, L. salivarus, L. casei, L. brevis, L. plantarum, L. buchneri, Saccharomyces cerevisiae, Penicillium damnosus*	Alcoholic beverage	Nigeria, Ghana
Chee-fan	Soybean wheat curd	*Mucor, Aspergillus glaucus*	Cheese-like product, eaten fresh	China
Chicha	Maise	*Aspergillus*, *Penicilliu*m, yeasts, bacteria	Spongy solid eaten with vegetables	Peru
Chikokivana	Maise and millet	*Saccharomyces cerevisiae*	Alcoholic beverage	Ziombabwe
Chinese yeast	Soybeans	*Mucoraceous* molds, yeasts	Solid eaten fresh with rice	China
Chongju	Rice	*Saccharomyces cerevisiae*	Alcoholic clear drink	Korea
Dalaki	Millet	Unknown	Thick porridge	Nigeria
Darassum	Millet	Unknown	Liquid drink	Mongolia
Dhokla	Rice or wheat and bengal gram	*Leuconostoc mesenteroides, Streptococcus faecalis Torulopsis candida, T. pullulans*	Steamed cake for breakfast or snack food	Northern India

(*Continued on next page*)

Table 3 (*continued*)

Product	Substrates	Microorganisms	Nature of use	Regions
Doro	Finger millet malt	Yeasts and bacteria	Colloidal thick alcoholic drink	Zimbabwe
Dosa	Rice and bengal gram	*Leuconostoc mesenteroides, Streptococcus faecalis, Torulopsis candida, T. pullulans*	Griddled cake for breakfast or snack food	India
Hamanatto	Wheat, soybeans	*Aspergillus oryzae, Streptococcus, Pediococcus*	Raisin-like, soft, flavouring agent for meat and fish, eaten as snack	Japan
Idli	Rice grits and black gram	*Leuconostoc mesenteroides, Streptococcus faecalis, Torulopsis, Candida, Tricholsporon pullulans*	Steamed cake for breakfast food	South India, Sri Lanka
Ilambazi lokubilisa	Maise	LAB, yeasts and moulds	Porrridge as weaning food	Zimbabwe
Injera	Sorghum, tef, maise or wheat	*Candida guilliermondii*	Bread-like staple	Ethiopia
Jaanr	Millet	*Hansenula anomala, Mucor rouxianus*	Alcoholic paste mixed with water	India, Himalaya
Jalebies	Wheat flour	*Saccharomyces bayanus*	Pretzel-like syrup-filled confection	India, Nepal, Pakistan
Jamin-bang	Maise	Yeasts, bacteria	Bread, cake-like	Brazil
Kaanga-Kopuwai	Maise	Bacteria, yeasts	Soft, slimy eaten as vegetable	New Zealand
Kachasu	Maise	Yeasts	Alcoholic beverage	Zimbabwe
Kaffir beer	Kaffir corn	Yeasts, LAB	Alcoholic drink	South Africa
Kanji	Rice and carrots	*Hansenula anomala*	Liquid added to vegetables	India
Kecap	Wheat, soybeans	*Aspergillus oryzae, Lactobacillus, Hansenula, Saccharomyces*	Liquid flavouring agent	Indonesia
Kenkey	Maise	*Lactobacillus fermentum, L. reuteri, Candida, Saccharomyces, Penicillium, Aspergillus and Fusarium*	Mush, steamed eaten with vegetables	Ghana
Khanomjeen	Rice	*Lactobacillus, Streptococcus*	Noodle	Thailand
Khaomak	Rice	*Rhizopus, Mucor, Saccharomyces, Hansenula*	Alcoholic sweet beverage	Thailand
Kichudok	Rice, takju	*Saccharomyces*	Steamed cake	Korea
Kishk	Wheat and milk	*Lactobacillus plantarum, L. brevis, L. casei, Bacillus subtilis* and yeasts	Solid, dried balls, dispersed rapidly in water	Egypt, Syria, Arabian countries
Kisra	Sorghum	Unknown	Staple as bread	Sudan
Koko	Maise	*Enterobacter clocae, Acinetobacter., Lactobacillus platarum, L. brevis, Saccharomyces cerevisiae, Candida mycoderma*	Porridge as staple	Ghana
Kwunu-Zaki	Millet	LAB, yeasts	Paste used as breakfast dish	Nigeria
Kurdi	Wheat	Unknown	Solid, fried crisp, salty noodles	India

(*Continued on next page*)

Table 3 (*continued*)

Product	Substrates	Microorganisms	Nature of use	Regions
Lao-chao	Rice	*Rhizopus oryzae, R. chinensis, Chlamydomucor oryzae, Saccharomycopsis*	Paste, soft, juicy, glutinous consumed as such, as dessert or combined with eggs, seafood	China, Indonesia
Mahewu	Maise	*Streptococcus lactis*	Solid staple	South Africa
Mawe	Maise	LAB, yeast	Basis for preparation of many dishes	South Africa
Mangisi	Millet	Unknown	Sweet-sour non-alcoholic drink	Zimbabwe
Mantou	Wheat flour	*Saccharomyces*	Steamed cake	China
Me	Rice	LAB	Sour food ingredient	Vietnam
Merissa	Sorghum and millet	*Saccharomyces*	Alcoholic drink	Sudan
Minchin	Wheat gluten	*Paecilomyces, Aspergillus, Cladosporium, Fusarium, Syncephalastum, Penicillium* and *Trichothecium*	Solid as condiment	China
Mirin	Rice, alcohol	*Aspergillus oryzae, A. usamii*	Alcoholic liquid seasoning	Japan
Miso	Rice and soy beans or rice other cereals such as barley	*Aspergillus oryzae, Torulopsis etchellsii, Lactobacillus*	Paste used as seasoning	Japan, China
Munkoyo	Kaffir corn, millet or maise plus roots of munkoyo	Unknown	Liquid drink	Africa
Mutwiwa	Maise	LAB, bacteria and moulds	Porridge	Zimbabwe
Nan	Unbleached wheat flour	*Saccharomyces cerevisiae*, LAB	Solid as snack	India, Pakistan, Afghanistan, Iran
Nasha	Sorghum	*Streptococcus, Lactobacillus, Candida, Saccharomyces cerevisiae*	Porridge as a snack	Sudan
Ogi	Maise, sorghum or millet	*Lactobacillus plantarum, Saccharomyces cerevisiae, Candida mycoderma, Corynebacterium*, *Aerobacter*, *Rhodotorula*, *Cephalosporium, Fusarium, Aspergillus* and *Penicillium*	Paste as staple. For breakfast or weaning food for babies	Nigeria, West Africa
Otika	Sorghum	Unknown	Alcoholic beverage	Nigeria
Papadam	Black gram	*Saccharomyces*	Breakfast or snack food	India
Pito	Maise, sorghum, maise and sorghum	*Geotrichum candidum, Lactobacillus*, *Candida*	Alcoholic dark brown drink	Nigeria, Ghana
Pozol	Maise	Molds, yeasts, bacteria	Spongy dough formed into balls; basic food	Southeasters Mexico
Puto	Rice, sugar	*Leuconostoc mesenteroides, Strepromyces faecalis*, yeasts	Solid paste as seasoning agent, snack	Philippines
Rabdi	Maise and buttermilk	*Penicillium acidilactici, Bacillus, Micrococcus*	Semisolid mash eaten with vegetables	India

(*Continued on next page*)

Table 3 (*continued*)

Product	Substrates	Microorganisms	Nature of use	Regions
Sake	Rice	*Saccharomyces sake*	Alcoholic clear drink	Japan
Seketeh	Maise	*Saccharomyces cerevisiae, S. chevalieri, S. elegans, Lactobacillus plantarum, L. lactis, Bacillus subtilis, Aspergillus niger, A. flavus, Mucor rouxii*	Alcoholic beverage	Nigeria
Shaosinghjiu	Rice	*Saccharomyces cerevisiae*	Alcoholic clear beverage	China
Shoyu (soy sauce)	Wheat and soybeans	*Aspergillus oryzae* or *A. soyae, Lactobacillus, Zygosaccharomyces rouxi*	Liquid seasoning	Japan, China, Taiwan
Sierra rice	Rough rice	*Aspergillus flavus, A. candidus, Bacillus subtilis*	Brownish-yellow dry rice	Ecuador
Sorghum beer	Sorghum, maise	LAB, yeasts	Liquid drink, acidic, weakly alcoholic	South Africa
Soybean milk	Soybeans	LAB	Drink	China, Japan
Takju	Rice, wheat	LAB, *Saccharomyces cerevisiae*	Alcoholic turbid drink	Korea
Talla	Sorghum	Unknown	Alcoholic drink	Ethiopia
Tao-si	Wheat and soybeans	*Aspergillus oryzae*	Seasoning	Philippines
Taotjo	Roasted wheat meal or glutinous rice and soybeans	*Aspergillus oryzae*	Condiment	East India
Tapai pulut	Rice	*Chlamydomucor, Endomycopsis, Hansenula*	Alcoholic dense drink	Malaysia
Tape ketan	Rice or cassava	*Saccharomyces cerevisiae, Hansenula anomala, Rhizopus oryzae, Chlamydomucor oryzae, Mucor, Endomycopsis fibuliger*	Soft, alcoholic solid staple	Indonesia
Tapuy	Rice	*Saccharomyces, Mucor, Rhizopus, Aspergillus, Leuconostoc, Lactobacillus plantarum*	Sour sweet alcoholic drink	Philippines
Tarhana	Parboiled wheat meal and yoghurt (2:1)	LAB	Solid powder, dried seasoning for soups	Turkey
Tauco	Cereals and soybeans	*Rhizopus oligosporus, Aspergillus oryzae*	Seasoning	West Java (Indonesia)
Tesgüino	Maise	Bacteria, yeasts and molds	Alcoholic beverage	Northern and North Western Mexico
Thumba	Millet	*Endomycopsin fibuliger*	Liquid drink	Eastern India
Tobwa	Maise	LAB	Non-alcoholic drink	Zimbabwe
Torani	Rice	*Hansenula anomala, Candida quilliermondii, C. tropicalis, Geotrichum candidum*	Liquid as seasoning for vegetables	India
Uji	Maise. Sorghum, millet	*Leuconostoc mesenteriodes, Lactobacillus platarum*	Porridge as a staple	Kenia, Uganda, Tanganyika
Vada	Cereal/legume	*Pediococcus, Streptococcus, Leuconostoc*	Breakfast or snack food	India

3. Indigenous rice-based fermented foods

3.1. Idli

A fermented, thick suspension made of a blend of rice (*Oryza sativum*) and dehulled black gram (*Phaseolus mungo*) is used in several traditional foods in Southeast Asian countries. Among them, *idli* and *dosa* are very popular in India and Sri Lanka (Sands & Hankin, 1974). Traditionally, for *idli* preparation the rice and black gram are soaked separately. After draining the water, rice and black gram are grinded independently, with occasional addition of water during the process. The rice is coarsely ground and the black gram is finely ground. Then the rice and the black gram batters are mixed together (2:1 ratio) with addition of a little salt and allowing to ferment overnight at room temperature (about 30 °C). Finally, the fermented batter is placed in special *idli* pans and steamed for 5–8 min (Nagaraju & Manohar, 2000).

The lactic acid bacteria *Leuconostoc mesenteroides, Streptococcus faecalis, Lactobacillus delbrueckii, Lactobacillus fermenti, Lactobacillus lactis* and *Pediococcus cerevisiae* have been found to be responsible for the fermentation process, although *L. mesenteroides* and *S. faecalis* are considered to be the microorganism essential for leavening of the batter and for acid production in *idli* (Purushothaman, Dhanapal, & Rangaswami, 1993; Ramakrishnan, 1993). The yeasts *Geotrichum candidum*, *Torulopsis holmii*, *Torulopsis candida* and *Trichosporon pullulans* have also been identified in *idli* fermentation (Chavan & Kadam, 1989; Shortt, 1998). Fermentation of *idli* batter appears to have a significant effect on the increase of all essential amino acids and in the reduction of antinutrients (such as phytic acid), enzyme inhibitors and flatus sugars (Steinkraus et al., 1993).

Idli is a low calorie, starchy and nutritious food, which is consumed as breakfast or snack. Steamed *idli* contains about 3.4% protein, 20.3% carbohydrate and 70% moisture (Teniola & Odunfa, 2001). Large-scale production of *idli* is carried out in batch compartmental steaming units. This is labour intensive and has limited capacity. With the growing demands for breakfast foods, *idlis* are being consumed on a large scale in some Indian institutions such as army, railways, industrial canteens, etc. In order to meet the demand, numerous studies are carried out for the development of continuous units for the production of *idli* (Murthy, Nagaraju, Rao & Subba Rao, 1994; Murthy & Rao, 1997; Nagaraju & Manohar, 2000).

3.2. Dosa

It is very similar to *idli* batter except that the rice and black gram are finely ground and that the fermented suspension instead of being steamed is heated with a little oil, on a flat plate. A *dosa* suspension is prepared by grinding wet rice and black gram separately with water. The two suspensions are then mixed and allowed to undergo natural fermentation, usually for 8–20 h. To make a *dosa*, the fermented suspension is spread in a thin layer (of 1–5 mm thickness) on a flat heated plate, which is smeared with a little oil or fat. A sol to gel transformation occurs during the heating and within a few minutes, a circular, semi-soft to crisp product resembling a pancake, ready for consumption is obtained (Battacharya & Bhat, 1997). The microbiological, physical and biochemical changes of *dosa* during fermentation and its nutritive value are quite similar to *idli* (Chavan & Kadam, 1989; Purushothaman et al., 1993; Ramakrishnan, 1993; Sands & Hankin, 1974; Shortt, 1998).

3.3. Dhokla

Dhokla is also similar to *idli* except that Bengal gram dhal is used instead of black gram dhal in its preparation. A mixture of rice and chickpea flour is also used as the substrate for the fermentation. As in *idli* preparation, the fermented batter is poured into a greased pie tin and steamed in an open steamer (Chavan & Kadam, 1989; Purushothaman et al., 1993; Ramakrishnan, 1993). As in other indigenous fermented foods, a significant improvement in the biological value and net protein utilisation of *dhokla* due to fermentation has been reported (Aliya & Geervani, 1981; Sands & Hankin, 1974).

4. Traditional wheat-based fermented foods

4.1. Soy sauce

Soy sauce is a dark brown liquid, made from a blend of soybeans and wheat, that is mainly used as an all-purpose seasoning in Japan, China and the Far East countries (Yokotsuka, 1993). Soy sauces have a salty taste, but are lower in sodium than traditional table salt. The traditional manufacturing techniques for soy sauce have been well described (Beuchat, 1983; Xu, 1990; Yokotsuka & Sasaki, 1998). Cooked soybeans are mixed with coarse wheat flour, with adjustment of the initial moisture of the mixture to about 55% (w/w). The soybean–wheat mixture is inoculated by molds, and after 3 days of fermentation at 25–35 °C, the soybeans and flour mixture (known as *koji* at this stage) is immersed in a brine solution (22–25%, the ratio of *koji* to brine is about 1:3 w/v). After mixing, the salt concentration of the mixture usually falls around 18–21%. This brine solution containing *koji* is known as *moromi*. The *moromi* is left to ferment for a period of 1–12 months; the longer the fermentation time the better the soy sauce quality. After the *moromi* fermentation is completed, the liquid part (soy sauce) is separated, filtered, pasteurised and bottled (Ayres, Steinkraus, Olek, & Farr, 1993; Franta, Steinkraus, Mattick, Olek, & Farr, 1993; Mensah, 1997; Rowan, Anderson, & Smith, 1998; Steinkraus, 1998).

There have been many studies describing the involvement of various microorganisms in soy sauce fermentation and three major groups have been reported in the literature (Horitsu, Wang, & Kawai, 1991; Scheinbach, 1998; Yeoh, 1995; Yong & Wood, 1974, 1976, 1977). These include fungi such as *Aspergillus oryzae* and *A. soyae* involved in the *koji* production, halotolerant LAB and yeast strains such as *Zygosaccharomyces rouxii* and *Candida* species responsible for the *moromi* fermentation (Allen, Linggood, & Porter, 1996; Hamada, Sugishita, Fukushima, Fukase, & Motai, 1991; Holzapfel, Haberer, Snel, Schillinger, & Veld, 1998; Röling, Apriyantono, & Van Verseveld, 1996).

The characteristic aroma and flavour of soy sauce is due to the enzymatic activities of yeasts and some LAB. As soybeans contain high levels of proteins and oligosaccharides, but no significant level of simple sugars, fermentation by lactic acid bacteria and yeasts requires the exogenous saccharifying enzymes supplied by the koji. In general the pH of the sauce is between 4.6 and 4.8, and the typical salt concentration is 17–19%. Concentration of salt less than 16% can result in the development of putrefactive species during fermentation and ageing. On the contrary, levels greater than 19% interfere with the growth of halophilic bacteria such as *Pediococcus halophilus* and osmotic yeasts such as *Z. rouxii* (Beuchat, 1983).

During the last 2–3 decades the traditional process for soy sauce production has been significantly improved. Some examples of these developments include the introduction of improved microbial inocula for soy sauce fermentation, the use of new techniques for preparing *koji*, and the use of new materials and modern technology for processing and fermentation (Mensah, 1997).

4.2. Kishk

Fermented milk–wheat mixtures, known as *kishk* in the Middle East and *tarhana* in Greece and Turkey, are important foods in the diet of many populations. In addition to their well-established position in the dietary patterns of the people in the aforementioned countries, these products have been promoted in Mexico (Cadena & Robinson, 1979) and Europe (Berghofer, 1987).

Kishk (*Fugush*) is typically prepared by adding strained yoghurt to *bulgur* (cracked and bran-free parboiled wheat) and allow the mix to ferment at ambient temperature for different periods of time. The wheat grains are boiled until soft, dried, milled and sieved in order to remove the bran. Milk is separately soured in a container, concentrated and mixed with the moistened wheat flour. The milk undergoes a lactic fermentation and the resulting paste is dried to a moisture content of 10–13% and then ground into a powder. The product is stored in the form of dried balls, brownish in colour with a rough surface and hard texture. The processing, composition and sensory properties of *kishk* have been the subject of a recent review (Tamang, Thapa, Tamang, & Rai, 1996). The microorganisms responsible for the fermentation include *Lactobacillus plantarum, Lactobacillus casei and Lactobacillus brevis, Bacillus subtilis* and yeasts (Beuchat, 1983; Chavan & Kadam, 1989).

Kishk is a balanced food with excellent preservation quality, richer in B vitamins than either wheat or milk, and well adapted to hot climates by its content of lactic acid (Abd-el-Malek & Demerdash, 1993; Mahmoud, 1993; Morcos, 1993). Some modifications, such as the substitution of whole wheat-meal for *bulgur*, have been proposed in the formulation of *kishk*. It has been found that substitution of whole wheat-meal for *bulgur* enhances the availability of Ca, Fe, Mg and Zn and provides a better means for the utilization of wheat nutrients, without undue effects on the acceptability of the final product. Sensorily, the whole wheat-meal *kishk* is sourer, less cohesive, less gritty, contains more bran particles and is more yellowish in colour than the traditional bulgur *kishk*. The production costs are lower and whole wheat meal is nowadays an ingredient in the formulation of *kishk* (Tinay, Addel Gadir, & Hidai, 1979).

4.3. Tarhana

Tarhana (*Trahanas*) is prepared by mixing wheat flour, sheep milk yoghurt, yeast and a variety of cooked vegetables and spices (tomatoes, onions, salt, mint, paprika) followed by fermentation for 1–7 days. The fermented matter is dried and stored in the form of biscuits (Campbell-Platt, 1994). The fermentation process and the type of product obtained is very similar to *kishk*. The sheep milk yoghurt contains *Steptococcus thermophilus* and *Lactobacillus bulgaricus* as the major fermenting organisms (Economidou & Steinkraus, 1993).

Tarhana has an acidic and sour taste with a strong yeasty flavour, and is a good source of protein and vitamins. While *tarhana* soup can be used as a part of any meal, it is often eaten for breakfast. The practical nutritional importance of *tarhana* is the improvement of the basic cereal protein diet by adding dairy protein in a highly acceptable form. The low pH (3.8–4.2) and low moisture content (6–9%) make *tarhana* a poor medium for pathogens and spoilage organisms. In addition, *tarhana* powder is not hygroscopic and it can be stored for 1–2 years without any sign of deterioration (Haard et al., 1999).

5. Traditional corn-based fermented foods

5.1. Ogi

Ogi is a fermented cereal gruel processed from maise, although sorghum or millet are also employed as the substrate for fermentation. It is considered the most important weaning food for infants in West Africa although it is also consumed by adults (Banigo, 1993; Moss, Mpuchane, & Murphy, 1993; Onyekwere, Akinrele, & Koleoso, 1993). Along the West African coastal region the product is given other names such as *eko, agidi, kamu, akamu, koko* and *furah* depending on the substrate used and the form in which it is eaten.

For the preparation of ogi, the cereal grains are steeped in earth ware, plastic or enamel pots for 1–3 days. Lactic acid bacteria, yeasts and moulds are responsible for the fermentation, although *Lactobacillus plantrium* is the predominant microorganism. Other bacteria such as *Corynebacterium* hydrolyse the corn starch, and then yeasts of the *Saccharomyces* and *Candida* species also contribute to flavour development (Caplice & Fitzgerald, 1999). The fermented grains are wet-milled and wet-sieved to yield the *ogi* slurry (Iwasaki, Nakajima, Sasahara, & Watanabe, 1991; Steinkraus, 1998).

The nutritional qualities of *ogi* has been studied and it has been found that during the fermentation phosphorous is released from phytate (Lopez, Gordon, & Field, 1983) and niacin and riboflavin contents increase (Kuboye, 1985). However, approximately 20–50% of the nutrients available in the original cereal grains are lost through processing for *ogi* production, being the loss of aleurone layer and germ of grains during wet milling and wet sieving the reason for this (Adeyemi, 1983; Akinrele & Bassir, 1967). Specifically, amino acid analysis of *ogi* and its raw materials indicate substantial losses in lysine and tryptophan (Adeniji & Potter, 1978; Banigo & Muller, 1972; Makinde & LaChance, 1976). To avoid these losses, lysine and methionine excreting mutants of *Lactobacillus* and yeasts have been used to fortify *ogi* (Odunfa & Oyewole, 1998; Tanasupawat & Komagata, 1995).

The colour of *ogi* depends on the cereal grain used: cream-white for maise, reddish brown for sorghum, and dirty grey for millet (Banigo, 1993; Onyekwere et al., 1993). *Ogi* has a sour flavour similar to that of yoghurt and a distinctive aroma, which makes it different from other known cereal-based fermented products (Chavan & Kadam, 1989).

5.2. Kenkey

Kenkey is a fermented maise dough eaten in Ghana. *Kenkey* can be prepared using two methods. In the first one, the maise grains are soaked in water at ambient temperature for 1–2 days, after which the water is drained before wet-milling the hydrolysed grain. The resulting maise meal is allowed to ferment spontaneously after the addition of water to produce a stiff dough (solid state fermentation). In the second method, the maise meal is strained to remove all chaff after the addition of a large volume of water, thus giving a smooth texture product. The mixture is allowed to ferment overnight. The water is discarded leaving a wet mash, which is used to cook porridge (McKay & Baldwin, 1990).

The fermentation is dominated by a variety of lactic acid bacteria, particularly *Lactobacillus fermentum* and *L. reuteri* (Halm, Lillie, Spreusen, & Jakobsen, 1993), though yeasts and moulds also contribute to flavour development. A mixed flora consisting of *Candida, Saccharomyces, Penicillium, Aspergillus* and*Fusarium* species were found to be the dominant organisms during the preparation of this product (Jespersen, Halm, Kpodo, & Jacobson, 1994).

5.3. Pozol

Pozol is a fermented maise dough with the form of balls of various shapes and sises. It is consumed in South-eastern Mexico by Indians and Mestizo groups, for whom it can be a main component of the daily diet. To prepare it, maise grains are boiled in limewater and coarsely ground. The resulting dough is kneaded to form a compact ball that is wrapped in banana leaves. It is left at ambient temperature from a few hours to several days or even more than a month. A complex microbial community that is incorporated mainly during the grinding procedure ferments the dough (Nanson & Field, 1984; Wacher, 1993). *Lactococcus lactis, Streptococcus suis, Lactobacillus plantarum, Lactobacillus casei, Lactobacillus alimentarium*, *Lactobacillus delbruekii* and *Clostridium* sp. have been identified in pozol (Escalante, Wacher, & Farres, 2001).

6. Traditional sorghum-based fermented foods

6.1. Injera

Injera (*Enjera*) is the undisputed national food of Ethiopians (Chavan & Kadam, 1989; Oda, Hasegawa, Komatsu, Jambe, & Tsuchiya, 1983). It can be made from different cereals, including sorghum, tef, corn, finger millet and barley, although tef (*Eragrostis tef*) is the major cereal ingredient in Ethiopian *injera*. Kebede and Menkir (1984) reported that sorghum ranks second to tef in preference for making *injera*. This could be due to the relative brittleness and dryness of sorghum *injera* after storage (Zegeye, 1997).

To make *injera* the grains are dehulled manually or mechanically and milled into flour. This flour is mixed with water to form a dough, the starter (*ersho*) is added, and the dough is fermented for 2 or 3 days. The starter is a fluid saved from previously fermented dough. After fermentation the dough is thinned down to a thick batter and poured onto a lightly oiled pan, which is then covered with a tightly fitting lid to retain the steam (Parker, Melaku, & Faulks, 1989). Within about 2–3 min it is ready to be removed from the pan and then is placed on a basket. The storage period does not usually exceed 3 days at room temperature.

The microorganisms involved in fermentation of *injera* are mainly yeasts, some fungi including *Pullaria* sp., *Aspergillus* sp., *Penicillium* sp., *Rhodotorula* sp., *Hormodendrum* sp., *Candida* sp. and number of unidentified bacteria (Ashenafi, 1993; Dirar, 1993a; Gashe, Girma, & Bisrat, 1993; Steinkraus, 1983; Vogel, Gobezie, & Gifawesen, 1993). A normal and typical *injera* is round, soft, spongy and resilient, about 6 mm thick, 60 cm in diameter with uniformly spaced honeycomb-like "eyes" on the top (Gebrekidan & Gebrettiwat, 1982). The major quality attribute of a good injera is its slightly sour flavour. Injera has a very high nutritional value, as it is rich in calcium and iron (Zegeye, 1997).

6.2. Kisra

Kisra (*Aseeda or Aceda*) is similar to *injera* and it is consumed throughout the Arabian Gulf, Sudan and Iraq (Oda et al., 1983). *Kisra* is make from a fermented dough of sorghum (*Sorghum bicolor*) or pearl millet flour (*Pennisetum typhodium*; Thakur, Prasad, & Rastogi, 1995). The fermented dough is baked into thin sheets and it is eaten with certain types of stew prepared from vegetables and meat.

The main microorganisms isolated in *kisra* are *Lactobacillus* sp., *Acetobacter* sp. and *S. cerevisiae*. Other microorganisms may be present but they have not been identified (Abdel Gadir & Mohamed, 1993; Chavan & Kadam, 1989; Dirar, 1993b). The effects of the traditional methods of fermentation, germination and baking of *kisra* on their contents of thiamine, riboflavin and some mineral elements have been investigated. Fermentation of *kisra* increased riboflavin, significantly decreased thiamine, but caused no significant effect on the mineral contents (Mahgoub, Ahmed, Ahmed, & El Agib El Nazeer, 1999).

7. Traditional cereal-based fermented beverages

There are several types of cereal-based fermented drinks produced around the world, which can be classified based on the raw materials used or the type of fermentation involved in the manufacturing process. Alcoholic fermented beverages can be classified into wines and beers, while the great majority of non-alcoholic fermentations are souring, mainly lactic acid fermentations (Chavan & Kadam, 1989; Fleet, 1998).

7.1. Beers

The technology for production of European barley beer and the biochemical and microbiological changes that take place during malting, fermentation and subsequent processing and storage are well documented in the literature, and it is not the objective of this paper to give an in-depth description of the process. In Africa traditional beers differ from the western-type; they are often sour, less carbonated and have no hops. They are consumed unrefined, including unfermented substrates and microorganisms (Haggblade & Holzapfel, 1989, 1993). *Pito* and *burukutu* are brewed concurrently by fermenting malted or germinated single cereal grains or a mixture of them. *Pito* is a cream-coloured liquor while *burukutu* is a brown-coloured suspension (Iwuoha & Eke, 1996; Uzogara, Agu, & Uzogara, 1990). Other examples of African brews are *ajon* from finger millet, *omuramba* from sorghum and *kweete* from maise and millet (Mwesigye & Okurut, 1995).

Rice beers are typically prepared in the Asia-Pacific countries. Those brews include Korean *takju*, Philippine *tapuy*, Indonesian *brem bali* and Indian *jaanr* (Banigo & Muller, 1972; Sankaran, 1998; Steinkraus, 1998; Svanberg & Sandberg, 1988).

7.2. Sake

Sake (*rice wine*) is a traditional alcoholic beverage, prepared from rice, consumed particularly in Japan and China (Lotong, 1998). The rice is polished and steamed, and part of it is steamed and used to grow *Aspergillus oryzae*, which produces different types of enzymes required for sake brewing. The seed mash is traditionally obtained by natural lactic acid fermentation involving various aerobic bacteria, wild yeasts, lactic acid bacteria, and sake yeasts (Chavan & Kadam, 1989; Lotong, 1998; Yokotsuka & Sasaki, 1998; Yoshizawa & Ishikawa, 1989). The Sake production process is also well described in the literature and will not be reviewed in this article in detail.

7.3. Bouza

Bouza is a fermented alcoholic wheat beverage known since the times of the pharaohs. It is a light yellow, thick, sour drink consumed mainly in Egypt, Turkey and in some Eastern Europe countries (Morcos, Hegazi, & Ell-Damhoughy, 1973). It is prepared by coarsely grinding wheat grains, placing a portion of them in a wooden basin and kneading them with water into a dough. The dough is cut into thick loaves, which are lightly baked. The remainder of the grains is moistened with water, germinated, dried, ground and mixed with the loaves of bread, which are soaked in water.

The biochemical changes of wheat occurring during bouza fermentation have been studied by Morcos, Hegazi, and Ell-Damhoughy (1993) who found that the low pH (3.9–4.0) and the high acidity of bouza indicate a fermentation by lactic acid bacteria, while the alcohol is due to yeast fermentation. The protein content of bouza ranges from 1.5 to 2.0% and due to the alcoholic fermentation involved in its formation, a significant contribution of vitamin B can be expected.

7.4. Chicha

Chicha is a fermented corn product widely consumed in South America (Chavan & Kadam, 1989; Steinkraus et al., 1993). *Chicha* preparation is a unique fermentation process in which, traditionally, saliva serves as the source of amylase for the conversion of starch to fermentable sugars (Escobar, Gardner, & Steinkraus, 1993). Yeasts, particularly *S. cerevisiae*, and bacteria of the genus *Lactobacillus* sp., *Leuconostoc* sp., *Acetobacter* sp. with various moulds such as *Aspergillus* sp. are the primary fermenting microorganisms in *chicha* (Haard et al., 1999).

7.5. Mahewu

Mahewu (*amahewu*) is an example of a non-alcoholic sour beverage made from corn meal, consumed in Africa and some Arabian Gulf countries (Chavan & Kadam, 1989). It is an adult-type of food, although is commonly used to wean children (Shahani, Friend, & Bailey, 1983). It is prepared from maise porridge, which is mixed with water. Sorghum, millet malt or wheat flour is then added and left to ferment (Odunfa, Adeniran, Teniola, & Nordstrom, 2001). The fermentation is a spontaneous process carried out by the natural flora of the malt at ambient temperature (Gadaga, Mutukumira, Narvhus, & Feresu, 1999). The predominant microorganisms in the spontaneous fermentation of the African *mahewu* belongs to *Lactococcus lactis* subsp. *Lactis* (Steinkraus et al., 1993). The industrial production of *mahewu* is successfully carried out in Zimbawe (Bvochora, Reed, Read, & Zvauya, 1999; Mutasa & Ayebo, 1993).

7.6. Boza

Boza is a colloid suspension, from light to dark beige, sweet, slightly sharp to slightly sour, non-alcoholic beverage consumed daily in Bulgaria, Albania, Turkey, and Romania. It is made from wheat, rye, millet, maise and other cereals mixed with sugar or saccharine (Hancioglu & Karapinar, 1997). Due to its pleasant taste, flavour, and high nutritional values, *boza* has become a very popular beverage consumed as everyday food by people of all ages. Microflora identification of Bulgarian boza shows that it mainly consists of yeasts and lactic acid bacteria, though the lactic acid bacteria are always predominant in the microbial association with an average LAB/yeasts ratio equal to 2.4 (Gotcheva, Pandiella, Angelov, Roshkova, & Webb, 2000). The lactic acid bacteria isolated has been identified as *Lactobacillus plantarum*, *Lb. acidophilus*, *Lb. fermentum*, *Lb. coprophilus*, *Leuconostoc raffinolactis*, *Ln. mesenteroides* and *Ln. brevis*. The yeasts isolated comprise *Saccharomyces cerevisiae*, *Candida tropicalis*, *C. glabrata*, *Geotrichum penicillatum* and *G. candidum* (Gotcheva et al., 2000). For the industrial production of boza, the grains are washed and cooked in an autoclave for about 2 h at 4–5 atmospheres. Between 3 and 1 volumes of water are used per volume of grains, and during the cooking process the mixture turns into a mash. Afterwards, the mash is gradually mixed with cold water at a ratio of 1:1 volume parts. The mash is percolated and then stored at 4C. A significant increase in glucose content is observed during the fermentation, while the pH, viscosity, free amino nitrogen content and dry matter decreases. Sugar or saccharine is added before bottling. *Boza* is acceptable for consumption at every stage of the fermentation until pH drops to about 3.5 (Gotcheva et al., 2001).

8. New cereal-based probiotic foods

Despite of the antimicrobial effects of the lactic acid bacteria from cereal-based fermented foods, the use of these microorganisms and their fermented products for the production of new probiotic foods is also a new tred. The term "probiotic" refers to a product containing mono or mixed cultures of live microorganisms, which when ingested will improve the health status and/or affect beneficially the host by improving its microbial balance (Salovaara, 1996). Most of the probiotics strains are isolated from human gut and belong to the group of lactic acid bacteria, of which *Lactobacillus* species are the most important (Table 4).

There are some new cereal-based fermented foods that are considered as probiotic products (e.g. yosa; Wood, 1997). Other traditional cereal-based fermented foods has been modified to aid the control of some diseases. An improved *ogi* named *Dogik* has been developed using a lactic acid starter with antimicrobial activities against some diarrhoeagenic bacteria (Okagbue, 1995).

8.1. Yosa

Yosa is a new snack food made from oat bran pudding cooked in water and fermented with LAB and

Table 4
Most common strains currently used in probiotic (Allen et al., 1996; Conway, 1996; Holzapfel et al., 1998; Salminen & Von Wright, 1998; Scheinbach, 1998; Shortt, 1998; Suskovic, Kos, Matosic, & Maric 1997)

***Bifidobacterium* spp.**	
B. adolescentis	*B. bifidum*
B. brevis	*B. longum*
B. animalis	*B. infantis*
B.thermophilum	*B. breve*
B. lactis	
***Lactobacillus* spp.**	
L. fermentum	*L. bulgaricus*
L. johnsonii	*L. crispatus*
L. salivarius	*L. bifidus*
L. rhamnosus or GG	*L. acidophilus*
L. reuteri	*L. plantarum*
L. helveticus	*L. casei* subsp. *rhamnosus*
L. gallinarum	*L. brevis*
L. delbrueckii subsp. *bulgaricus*	*L. gasseri*
L. cellobiosus	*L. vitulinus*
L. collinoides	*L. cremoris*
L. ruminis	*L. dextranicum*
L. lactis	*L. thamnosus*
L. lactis biover *oliacetylactis*	*L. casei*
L. casei shirota	
Others	
Propionibacterium freudenreichii	*Lactoccus lactis* subssp. *lactis* and *cremoris*
Enterococcus faecium	*Enterococcus faecalis*
Saccharomyces cerevisiae	*Saccharomyces boulardii*
Sporolactobacillus inulinus	*Escherichia coli*
Leuconostoc mesenteroides subsp. *dextranium*	*Leuconostoc paramesenteroides* or *lactis*
Bacillus cereus	*Pediococcus pentosaceus*
Pediococcus acidilactici	*Pediococcus halophilus*
Streptococcus diacetilactis	*Streptococcus salivarius* subsp. *thermophilus*
Streptococcus cremoris	*Streptococcus faecium*
Streptococcus lactis	*Streptococcus equinus*

Bifidobacteria. After fermentation, the matter is then flavoured with sucrose or fructose and fruit jam (Salminen & Von Wright, 1998). It is mainly consumed in Finland and other Scandinavian countries. It has a texture and a flavour similar to yoghurt but it is totally free from milk or other animal products (Toufeiliet al., 1997). It is lactose-free, low in fat, contains β-glucan and it is suitable for vegetarians (Bioferme Oy, 1999). Yosa is a healthy addition to the diet because it contains oat fibre and probiotic LAB which can maintain and improve the environment in the intestinal balance of the consumer (Toufeili et al., 1997). Oat fibre is also a good source of β-glucan, which can lower the cholesterol levels in the consumer blood, which in turn can reduce the risk of heart disease (Bioferme Oy, 1999).

9. Conclusions

Despite of the conventional foods and beverages largely produced from cereals in the Western world (breads, pastas and beers), there is a wide variety of products produced worldwide that have not received the scientific attention they deserve. These products are often fermented, and have an improved self-life and nutritional properties in comparison with the raw materials used. The flora responsible for the fermentation is in many cases indigenous and includes strains of lactic acid bacteria, yeast and fungi. Singles of mixed cereals sometimes mixed with other pulses are used, and the final texture of the product can vary according to the processing and fermentation conditions. Similar fermentation procedures have been used nowadays to develop new foods with enhanced health properties, which is a trend likely to continue in the future.

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