Chapter 1

Microorganisms in Fermented Foods and Beverages

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1.1 Introduction

Traditionally boiled rice is the staple diet with ethnic fermented and nonfermented legume products, vegetables, pickles, fish and meat on the side in the Far East, South and North Asia and the Indian subcontinent excluding western and northern India. In the west and north of India, wheat/barley-based breads/loaves is the staple diet together with milk and fermented milk products, meat and fermented meats. This diet is also followed in West Asia, Europe, North America and in Australia and New Zealand. Sorghum/maize porridges are the main diet with ethnic fermented and nonfermented sorghum/maize/millet, cassava, wild legume seeds, meat and milk products in Africa and South America (Tamang 2012a). Fermented foods are popular throughout the world and in some regions make a significant contribution to the diet of millions of individuals. The fermented food products supply protein, minerals, and other nutrients that add variety and nutritional fortification to otherwise starchy, bland diets.

Fermentation was traditionally a process which enabled the preservation of perishable food and has been used for centuries (www.eolss.net/sample-chapters/c06/e6-34-09-09.pdf; Hansen 2004). The term fermentation comes from the Latin word *fermentum* (to ferment). Throughout the world there are many different types of fermented foods, in which a range of different substrates are metabolized by a variety of microorganisms to yield products with unique and appealing characteristics. Fermented foods and alcoholic beverages are produced from raw materials or substrates of plant or animal origins mostly by natural fermentation or in the case of a few products by black-slopping or the addition of a traditionally prepared starter culture(s) containing functional microorganisms which modify the substrates biochemically and organoleptically into edible products that are socially acceptable to consumers (Tamang 2010b).

1.1.1 History of Fermented Foods

Methods for fermentation of vegetables might have developed in Asia (Pederson 1979), or in the Mediterranean (Hulse 2004), or in Europe (Tamang and Samuel 2010). Methods for pickling vegetables were well established during the Song dynasty in China (960–1279 AD), and have remained more or less the same to the present day (Tamang and Samuel 2010). *Suau cai*, the ethnic fermented mixed vegetable product of China, was one of the main meals for workers during the construction of the Great Wall of China in 300 BC (Pederson 1979). The history of *kimchi*, a fermented vegetable product of Korea, was traced back to 3–4 AD (Chang 1975). The traditional preparation of *kimchi* was mentioned in someKorean historical documents recorded during 1759–1829 AD (Cheigh 2002). *Sauerkraut* or *sauerkohl* meaning sour cabbage in German was documented in the seventeenth century (Pederson and Albury 1969). Olives were preserved or fermented with various methods in Roman times during 50–150 AD (Sealey and Tyers 1989). The oral history of the origin of some common Himalayan fermented vegetables such as *gundruk*, ethnic fermented leafy vegetables and *sinki*, ethnic fermented radish tap roots were documented by Tamang (2010a).

Bread-making is one of the oldest food processing practices in the food history of human beings. There are ample archaeological remains of tools and installations which were used to make bread in ancient Egypt (Samuel 2002), and descriptions of baking in Roman texts and tombs are available (Curtis 2001). About 250 bakeries were reported to have operated in ancient Rome around 100 BC (Pederson 1979). *Dosa*, the ethnic fermented pancake made from rice and black gram in South India was first noted in the Tamil Sangam literature in India about the sixth century AD (Srinivasa 1930). The traditional preparation of *idli,* an ethnic fermented rice-black gram food of India and Sri Lanka, eaten at breakfast, has been described by the poet Chavundaraya of South India in 1025 AD (Iyengar 1950). *Dhokla*, a fermented mixture of wheat and Bengal gram of western India was first mentioned in 1066 AD (Prajapati and Nair 2003). *Jalebi*, the fermented cereal-based pretzel-like product of India and Pakistan has been known since 1450 AD and is probably of Arabic or Persian origin (Gode 1943).

Soybean was probably introduced to India from China through the Himalayas several centuries ago and some believe that soybeans were also brought via Myanmar by traders from Indonesia (Shurtleff and Aoyagi 2010). *Kinema,* a fermented sticky soybean food of India, Nepal and Bhutan might have originated in east Nepal around 600 BC to 100 AD during the Kirat dynasty (Tamang 2010a). The word *kinema* was derived from the word *kinamba* of the Limboo language of the Kirat race, *ki* means fermented and *namba* means flavor (Tamang 2001). A hypothetical triangle "*natto*-triangle" was initially proposed by Nakao (1972) and was based on the distribution of plasmids (Hara et al. 1986, 1995) and the 16s RNA sequencing (Tamang et al. 2002) of the *Bacillus* species from common nonsalted sticky fermented soybean foods of Asia. An imaginary triangle known as "*Kinema-Natto-Thua nao* triangle" (KNT-triangle) was proposed by Tamang (2010a). Within the KNT-triangle in Asia only *Bacillus*-fermented soybean foods are prepared and consumed starting from Japan (*natto*), touching the Korean peninsula (*chungkokjang*), South China (*douchi*), North Thailand (*thua-nao*), Myanmar (*pepok*), Cambodia and Laos (*sieng*), southern Bhutan, the Darjeeling hills and Sikkim in India, and eastern Nepal (*kinem*a), and the North East Indian states of Meghalaya (*tungrymbai*), Manipur (*hawaijar*), Mizoram (*bekang*), Nagaland (*aakhone*), and Arunachal Pradesh (*peruyaan*). The proposed "KNT triangle" does not include nonsticky and nonbacilli fermented soybean products such as *tempeh, miso, sufu, shoyu,* and so on.

Asian fermented soybean foods might have originated from *douchi* or *tau-shi*, during the Han dynasty in southern China around 206 BC (Bo 1984a,b, Zhang and Liu 2000). *Natto*, a fermented sticky soybean, was introduced to Japan from China by Buddhist priests during the Nara period around 710–794 AD (Itoh et al. 1996, Kiuchi 2001). Production of *shoyu* and *miso* in China was recorded around 1000 BC with the transfer of knowledge of production of *shoyu* and *miso* to Japan in around 600 AD (Yokotsuka 1985). *Tempeh*, the mold-fermented soybean food of Indonesia was originally introduced by ethnic Chinese traders in the early seventeenth century and the earliest record of the word tempeh appeared in the Serat Centini manuscript around 1815 AD (Astuli 1999).

The oldest sacred books of the Hindus, the *Rig Veda* and the *Upanishads* mentioned the origin of *dahi,* one of the oldest yoghurt-like fermented milk products of India during 6000–4000 BC (Yegna Narayan Aiyar 1953). Some milk products of Sudan and Egypt consumed in modern Africa such as *rob* (made from cow/goat/sheep milk), *gariss* (from camel milk), *biruni* (cow/camel milk) of Sudan, and *mish* (cow/camel milk) were mentioned by medieval Arab travelers (Odunfa 1988, Dirar 1993). The ancient Turkish people in Asia who lived as nomads were the first to make yoghurt, called "yoghurut" (Rasic and Kurmann 1978). The Babylonian records refer to cheese in 2000 BC (Davis 1964). The importance of cheese in the food habits of people in Greece (1500 BC) and Rome (750 BC) has been well documented (Scott 1986).

The Mekong basin of south-west China, Laos and northern and north-west Thailand were the most probable place of origin of fermented fish products in Asia (Ishige 1993, Ruddle 1993). Consumption of sausage by the ancient Babylonians was recorded around 1500 BC (Pederson 1979). The name *salami* is believed to have originated from the city of Salamis located on the east cost of Cyprus, which was destroyed in 449 BC (Lücke 1985).

1.1.2 History of Alcoholic Drinks

Fermented beverages appeared in 5000 BC in Babylon, 3150 BC in Ancient Egypt, 2000 BC in Mexico and 1500 BC in Sudan (www.eolss.net/sample-chapters/c06/e6-34-09-09.pdf). The earliest evidence of the grape in Egypt is seeds in jars imported from the Levant, dating to about 3150 BC indicating that wine was possibly produced in Egypt itself by 3000 BC (Murray 2000). Archaeological findings and chemical analyses of residues recovered from the Neolithic (6th millennium BC) Hajji Firuz Tepe, and the Early Bronze Age (4th millennium BC) Godin Tepe, both in western Iran, is commonly reported to represent the earliest evidence of wine making (Renfrew 1999, Wilson 1999).

Early Mesopotamian beer was based on barley malt, that is, sprouted and dried grain (Curtis 2001). Analysis of ancient beer residues using scanning electron microscopy was more focused on archaeological evidence (Samuel 1996, 2000). The whole starch remaining in the unheated malt would have broken down more slowly and the source of fermentation is uncertain (Samuel 2000). Archaeobotanical evidence from northern Germany and Scandinavia shows that hops and sweet gale (*Myrica gale*) became important beer flavorings in early medieval times (ninth to tenth century AD) (Behre 1984).

Pulque, one of the ancient alcoholic beverages of South America, which is fermented from *agave* juice and now is the national drink of Mexico was inherited from the Aztecs (Goncalves de Lima 1975). Another ancient alcoholic drink of the Andes Indians living in the lower altitude regions of South America is *chicha*, prepared from maize through human saliva which serves as the source of amylase for conversion of starch into fermentation sugars (Escobar 1977).

During the *Vedic* period of Indian history (2500–200 BC), based originally around the Indus River system, alcoholic drink *soma rus* was common and was worshipped as the liquid god *Soma* because of its medicinal attributes (Bose 1922, Sarma 1939). Drinking of alcohol in India has been mentioned in the *Ramayana* during 300–75 BC (Prakash 1961). The malting process as well as wine fermentation is rarely used in traditional fermentation processes in Asia, instead, amylolytic mixed starters prepared from the growth of molds and yeasts on raw or cooked cereals are more commonly used (Tamang 2010c). The use of traditionally prepared amylolytic mixed starters, common to the Himalayas and South East Asia, might have its origins during the time of Euchok, the daughter of the legendary king of Woo of China, known as the goddess of rice-wine in Chinese culture in 4000 BC (Lee 1984). The first documentation of *chu*, the mixed amylolytic starter of China (use for production of fermented beverages and alcoholic drinks), was found in the Shu-Ching document written during the Chou dynasty (1121–256 BC) (Haard et al. 1999). The use of *chu* for fermentation of rice-based alcoholic beverages and drinks was recorded in the beginning of the Three Nations' Periods in Korea during first century BC to second century AD (Lee 1995). The word *ragi*, an amylolytic starter of Indonesia, was first noted on an ancient inscription called the Kembang Arum near Yogyakarta in Java around 903 AD (Astuli 1999). *Kodo ko jaanr*, the ethnic fermented finger millet alcoholic beverage of the Himalayas was mentioned in the history of Nepal during the Kirat dynasty in 625 BC to 100 AD (Adhikari and Ghimirey 2000). The Newar community of Nepal used to ferment alcoholic beverages from rice during the Malla dynasty in 880 AD (Khatri 1987). There are brief descriptions of the fermented millet beverages of the Darjeeling hills and Sikkim in India in historical documents (Hooker 1854, Risley 1928, Gorer 1938).

1.2 Protocol for Studying Fermented Foods

Protocols for studies of ethnic fermented foods and alcoholic beverages primarily focus on the following parameters (Tamang 2014):

1. Documentation of the indigenous knowledge of the local people of traditional preparation, culinary practices, mode of consumption, ethnical values, therapeutic uses, socio-economy, market survey of marginal producers of fermented foods/alcoholic beverages using standard format; photography.
2. Sensory character(s) of a fermented food or alcoholic beverage by a researcher: taste, texture, aroma/flavor, and appearance.
3. Calculation of per capita consumption and annual production of ethnic fermented foods and alcoholic beverages of the particular region/village.
4. Determination of pH, temperature of the product *in situ*.
5. Collection of samples aseptically in pre-sterile containers.
6. Microbiology of fermented foods: determination of microbial loads of microorganisms (bacteria, yeasts, molds) and pathogenic contaminants (colony forming unit per gram or liter of sample), isolation of cultivable microorganisms.
7. Identification of isolates: phenotypic (morphological, physiological, and biochemical tests) and molecular identifications, assigning the proper identification of functional microorganisms following the standard norm of ICBN for microorganisms and well-authenticated taxonomical keys.

8. Isolation of uncultured microorganisms directly from food samples, and identification by culture-independent molecular techniques.
9. Preservation of identified strains of microorganisms in 15% glycerol at 80°C, or lyophilized, and deposited at authorized culture collection centers.
10. Experiments on fermentation dynamics or microbial changes during *in situ* fermentation to understand the role of functional or nonfunctional microorganism(s) using culture-independent techniques during natural fermentation.
11. Determination of the proximate composition and nutritional values of the products.
12. Determination of functional properties: probiotics, antioxidants, antimicrobial activities, tyrosinase inhibition, cell proliferation and MMP-2 inhibition activities, degradation of antinutritive compounds, bioactive compounds, unsaturated fatty acids, including omega 3-fatty acids, isoflavones and saponins, total phenolic compounds, total anthocyanin, saponin, and so on.
13. Studies on food safety: occurrence of pathogenic and spoilage microorganisms, toxin production, shelf-life of the products.
14. Optimization of a traditional process using a starter culture(s), consisting either of a pure culture or of a consortium of identified native microorganism(s) with desirable functional properties.
15. Organoleptic evaluation and consumer preference trials of the product prepared on laboratory scale.

1.3 Microorganisms

Microorganisms determine the characteristics of fermented food, for example, acidity, flavor and texture, as well as the health benefits that go beyond simple nutrition (Vogel et al. 2011). Microorganisms may be present as the indigenous microbiota of the food or as a result of the intentional addition of microorganisms as starter cultures in an industrial food fermentation process (Stevens and Nabors 2009). Also, microbial cultures can be used to produce several compounds (enzymes, flavors, fragrances, etc.) either specifically for application as food additives or *in situ* as a part of food fermentation processes (Longo and Sanromán 2006).

With an estimated 5000 varieties of fermented foods and beverages, worldwide, only a small fraction of these artisanal products have been subjected to scientific studies so far (Tamang 2010b). In many of these foods, the biological and microbiological bases of the fermentation processes are poorly understood. What little information is available often deals with the identification and perhaps preliminary characterization of the primary microbiota in the finished product. This in turn will necessitate a more thorough understanding of the microorganisms involved, in terms of the types and their specific activities, so that the fermentation process can be made more reliable and predictable.

With the discovery of microorganisms, it became possible to understand and manage food fermentation. Methods for isolating and purifying microbial cultures became available in the nineteenth century. Sterilization or pasteurization of the raw materials prior to inoculation with well-defined cultures allowed the fermentation processes to be managed with little variation. The use of defined cultures became the industrial standard in breweries by the nineteenth century. During the twentieth century, the wine, dairy, and meat industries also shifted production procedures toward the use of well-characterized and defined starter cultures. In the beginning, starter cultures were isolates from earlier fermentations that were maintained and propagated at the site of production. The application of microbiology and process technology resulted in large improvements in the quality of the fermented food products. The quality improvements have been so great that today all significant production of fermented food is industrial. The small amount of "home fermentation" conducted in the form of baking, home brewing and private cheese making usually rely on commercially available yeast and bacterial cultures. The maintenance of the microorganisms differs between the different food industries in the sense that some fermentation industries, such as breweries and vinegar producers maintain their own stains and inocula. In the dairy industry, as well as in the meat industry and bakeries, cultures are usually obtained from suppliers dedicated to the production of high-quality food ingredients (Mogensen et al. 2002, Hansen 2004).

Fermentation can basically be performed either by natural or spontaneous fermentation, by back-slopping or by the addition of starter cultures. By spontaneous fermentation, the raw material and its initial treatment will encourage the growth of an indigenous microbiota. In most spontaneous fermentation, a microbial succession takes place: quite often lactic acid bacteria (LAB) will initially dominate followed by various species of yeasts. Molds only grow aerobically, limiting their occurrence in certain types of fermented products. LAB produce lactic acid and other antimicrobial substances that inhibit the growth of harmful bacteria along with reducing the sugar content, thereby prolonging the shelf life of the product. Yeasts mostly produce aroma components and alcohols. When molds are involved in fermentation, they generally contribute by producing both intra- and extracellular proteolytic and lipolytic enzymes that highly influence the flavor and texture of the product (Tamang and Fleet 2009).

In back-slopping, a part of a precious batch of a fermented product is used to inoculate the new batch. This procedure produces a higher initial number of beneficial microorganisms than that found in the raw material and ensures a faster and more reliable fermentation than that which occurs in spontaneous fermentation. Examples of back-slopping are home-made fermentation of milk, vegetables, and cereals (Josephsen and Jespersen 2004).

Novel insights into the metabolism of LAB offer perspectives for the application of a new generation of starter cultures. Functional starter cultures are starters that possess at least one inherent functional property. These can contribute to food safety and/or offer one or more organoleptic, technological, nutritional, or health advantage. The implementation of carefully selected strains as starter cultures or co-cultures in fermentation processes can help to achieve *in situ* expression of the desired property, maintaining a perfectly natural and healthy product. A functional LAB starter culture is able to produce antimicrobial substances, sugar polymers, sweeteners, aromatic compounds, useful enzymes, or nutraceuticals, while-the so-called probiotic strains, mainly LAB, exhibit health-promoting properties. Such functionalities also lead to a wider application area and higher flexibility of starter cultures (Leroy and De Vuyst 2004). Nowadays, there are many commercial suppliers of starter cultures worldwide, such as Alce and CSL (Italy), ASCRS (Australia), Chr. Hansen and Danisco (Denmark), CSK and DSM (the Netherlands), Degussa and Gewürzmüller (Germany), Lallemand (Canada), NZDRI (New Zealand), Quest International (UK), Rhodia (France), and so on. All companies can easily be found on the Internet/World wide Web (Hansen 2002, 2004).

Fermented foods are the hubs of consortia of microbiota and mycobiota (functional, nonfunctional, and pathogenic contaminants), which may be present as natural indigenous microbiota in uncooked plant or animal substrates, utensils, containers, earthen pots, or environments (Hesseltine 1983, Tamang 1998), or as a result of the intentional addition of the microorganisms as starter cultures in an industrial food fermentation process (Stevens and Nabors 2009). Functional microorganisms transform the chemical constituents of raw materials of plant/animal sources during fermentation thereby enhancing the nutritional value of the products, enriching them with improved flavor and texture, prolonging their shelf live, and fortifying them with health-promoting bio-active compounds (Farhad et al. 2010). Species of lactic acid bacteria and *Bacillus*, and amylolytic and alcohol-producing yeasts and filamentous molds are the major microbiota in the fermented foods and alcoholic beverages of Asia, whereas LAB or a combination of bacteria (LAB, non-LAB, micrococci)-yeast mixtures and filamentous molds are more prominent in Africa. Filamentous molds and bacilli are rare in the fermented foods and beverages of Africa, Europe, Australia, and America (Tamang 1998), although fermented legume products, based on *Bacillus* fermentation, are common in West Africa (Oguntoyinbo et al. 2007).

1.3.1 Isolation by Culture-Dependent and Culture-Independent Methods

The classical phenotypic identification methods are totally based on culture-dependent techniques for only cultivable microorganisms in culture media, ignoring several unknown uncultivable microorganisms that may have major or minor functional roles in the production of fermented foods. Direct DNA extraction from samples of fermented foods commonly referred to as culture-independent methods are nowadays commonly used in food microbiology to profile both cultivable and uncultivable microbial populations from fermented foods (Cocolin and Ercolini 2008). Culture independent techniques first appeared in food microbiology at the end of the 1990s and since then they have been applied extensively. These methods do not rely on cultivation and target nucleic acids (DNA and RNA) to identify and follow the changes that occur in the main populations present in a specific ecosystem (Cocolin et al. 2013). The most popular culture-independent technique being used in the isolation of microorganisms from fermented foods is a PCR-DGGE analysis to profile bacterial populations (Cocolin et al. 2011, Tamang 2014) and yeast populations in fermented foods (Cocolin et al. 2002, Jianzhonga et al. 2009). Culture-dependent and culture-independent methods are contradictory to each other (Alegría et al. 2011), but for microbial taxonomy both methods are equally important and complementary. Both cultivable and uncultivable microorganisms from any fermented food and beverage may be identified using culture-dependent and -independent methods to document a complete profile of native functional and nonfunctional microorganisms, and to study both inter- and intra-species diversity within a particular genus or among genera (Ramos et al. 2010, Yan et al. 2013, Tamang 2014). Greppi et al. (2013a) first reported the combination of both culture-dependent and independent methods to reveal predominant yeast species and biotypes in the traditional fermented maize foods of Benin. The DGGE analysis on the DNA directly extracted from fermented maize products demonstrated the presence of *Dekkera bruxellensis* and *Debaryomyces hansenii*, not detected by the culture-based approach (Greppi et al. 2013b).

1.3.2 Identification: Phenotypic and Biochemical

Phenotypic characteristics include colony appearance, cell morphology, Gram staining, growth at different temperatures (8–65°C), pH (3.9–9.6), and salt tolerance (4.0%–18%). Biochemical tests are based on the metabolic activities of microorganisms such as carbon and nitrogen sources, energy sources, sugar fermentation, secondary metabolite formation, and enzyme production (Tamang 2014). A few ready-to-use commercial identification kits are commonly used such as API 50CH (bioMérieux, France) for rapid sugar fermentation tests, and the Biolog Microbial Identification System, for identification of different groups of bacteria and yeasts.

1.3.3 Identification: Genotypic or Molecular

Molecular identification is emerging as an accurate and reliable identification tool, and is widely used in identification of both culture-dependent and culture-independent microorganisms from fermented foods. Owing to a variety of tools that provide advanced molecular differentiation of microorganisms, microbial populations can be quantified and new microbial species isolated and identified (Giraffa and Carminati 2008). Some common molecular tools used in identification of microorganisms isolated from fermented foods are species-specific PCR, qPCR, rep-PCR, AFLP, RAPD, DGGE, TGGE, ARDRA, mtDNA-RFLP, mCOLD-PCR, MLSA, and MLST.

Species-specific PCR primers are used to identify a particular species of the genus (Tamang et al. 2005); this technique is widely applied in the identification of LAB isolated from fermented foods (Robert et al. 2009). The application of real-time quantitative PCR (qPCR) with specific primers provides the specific detection and quantification of LAB species in fermented foods (Park et al. 2009). The repetitive extragenic palindromic sequence-based PCR (rep-PCR) technique permits typing at a subspecies level and reveals significant genotypic differences between strains of the same bacterial species from fermented foods (Tamang et al. 2008). Amplified fragment-length polymorphism (AFLP) is a technique based on the selective amplification and separation of genomic restriction fragments, and its applicability is for the identification of various LAB strains in fermented foods (Tanigawa and Watanabe 2011). Random amplification of polymorphic DNA (RAPD) is commonly used for discrimination of LAB strains from fermented foods (Schillinger et al. 2003, Chao et al. 2008). The amplified ribosomal DNA restriction analysis (ARDRA) technique using restriction enzymes is also useful in identification of uncultivable microorganisms from fermented foods (Jeyaram et al. 2010). The mt DNA-RFLP technique showed discriminating power similar to microsatellite typing and interdelta analysis (Schuller et al. 2007) and is considered as a useful genetic marker for *Saccharomyces cerevisiae* in amylolytic starters (Jeyaram et al. 2011). Techniques of denaturing gradient gel electrophoresis (DGGE) and temperature gradient gel electrophoresis (TGGE) have been developed to profile microbial communities directly from fermented foods, and are based on sequence-specific distinctions of 16S rDNA or 26S rDNA amplicons produced by PCR (Ongol and Asano 2009, Alegría et al. 2011). A modified CO-amplification at lower denaturation temperature PCR (mCOLD-PCR) method has been developed to detect low-abundant microorganisms using a double-strand RNA probe to inhibit the amplification of the sequence of a major microorganism in wine fermentation (Takahashi et al. 2014). Multilocus sequence analysis (MLSA) using housekeeping genes as molecular markers alternative to the 16S rRNA genes, has been proposed for LAB species identification from fermented foods (Naser et al. 2005, de Bruyne et al. 2007, 2008, 2010). Multilocus sequence typing (MLST) has also been used for discriminating LAB strains from fermented foods (Diancourt et al. 2007, Picozzi et al. 2010, Tanigawa and Watanabe 2011).

Effective tools of next-generation sequencing (NGS) such as phylobiomics, metagenomics, and metatranscriptomics are required for the documentation of cultures in traditional fermented products, for sensory quality and safety improvements, in some cases for starter culture design for commercialization and potentially for supporting sustainable food systems (van Hijum et al. 2013). A proteomics identification method using matrix-assisted laser desorption ionizing-time of flight mass spectrometry (MALDI-TOF MS) is used to identify the species of *Bacillus* in the fermented foods of Africa (Savadogo et al. 2011), *Lactobacillus* strains isolated from fermented foods (Dušková et al. 2012, Sato et al. 2012), sub-speciation of *Lactococcus* (*Lc.*) *lactis* (Tanigawa et al. 2010), LAB from traditional fermented vegetables of Vietnam (Nguyen et al. 2013b), probiotics from yoghurt (Angelakis et al. 2011), and *Tetragenococcus halophilus* and *Tetra. muriaticus* from fermented foods

(Kuda et al. 2014). The application of NGS such as metagenomic approaches using massively parallel pyrosequencing of tagged 16S rRNA gene amplicons provide detailed information on microbial communities associated with *kimchi* (Jung et al. 2011, Park et al. 2012), *nukadoko*, a fermented rice bran mash used for pickling vegetables in Japan (Sakamoto et al. 2011), *narezushi*, a fermented salted fish with cooked rice in Japan (Kiyohara et al. 2012), and *ben-saalga*, a traditional gruel of pearl millet in Burkina Faso (Humblot and Guyot 2009). The 16S rRNA gene sequence-based pyrosequencing method enables a detailed, comprehensive and high-throughput analysis of microbial ecology (Sakamoto et al. 2011), and this method has been applied to various traditional fermented foods (Oki et al. 2014). Compared to the pyrosequencing analysis, the DGGE method only revealed some of the major bacterial species such as *Bacillus thermoamylovorans* and *B. licheniformis* in *chungkokjang* (the sticky fermented soybean food of Korea) and could not detect a large number of predominant or diverse rare bacterial species identified in the pyrosequencing analysis. Also the regional differences of the bacterial community were more clearly represented in the pyrosequencing method than in the DGGE analysis (Nam et al. 2011).

Metabolomics, also called metabonomics or metabolic profiling, deals with the simultaneous determination and quantitative analysis of intracellular metabolites or low-molecular-mass molecules and can be used as a tool for the comprehensive understanding of fermented and functional foods with LAB (Mozzi et al. 2013). The application of species-independent functional gene microarray for identification of LAB in fermented foods has been developed (Weckx et al. 2009). Up-to-date analytical methods have also been applied in the identification and discrimination of some microbial species/strains from fermented foods such as length heterogeneity PCR (LH-PCR), high-throughput sequencing (HTS), BOX-PCR (Zhu et al. 2014), and so on.

1.4 Main Types of Microorganisms in Global Food Fermentation

Main types (with genera) of microorganisms associated with global fermented foods and beverages are grouped as follows (Bernardeau et al. 2006, Tamang and Fleet 2009, Tamang 2010a,b,c, Bourdichon et al. 2012, Alexandraki et al. 2013):

- Bacteria: *Acetobacter, Arthrobacter, Bacillus, Bifidobacterium, Brachybacterium, Brevibacterium, Carnobacterium, Corynebacterium, Enterobacter, Enterococcus, Gluconacetobacter, Hafnia, Halomonas, Klebsiella, Kocuria, Lactobacillus, Lactococcus, Leuconostoc, Macrococcus, Microbacterium, Micrococcus, Oenococcus, Pediococcus, Propionibacterium, Staphylococcus, Streptococcus, Streptomyces, Tetragenococcus, Weisella, Zymomonas.*
- Fungi: *Actinomucor, Aspergillus, Fusarium, Lecanicillium, Mucor, Neurospora, Penicillium, Rhizopus, Scopulariopsis, Sperendonema.*
- Yeasts: *Candida, Cyberlindnera, Cystofilobasidium, Debaryomyces, Dekkera, Hanseniaspora, Kazachstania, Galactomyces, Geotrichum, Guehomuces, Kluyveromyces, Lachancea, Metschnikowia, Pichia, Saccharomyces, Schizosaccharomyces, Schwanniomyces, Starmerella, Torulaspora, Trigonopsis, Wickerhamomyces, Yarrowia, Zygosaccharomyces, Zygotorulaspora.*

1.4.1 Bacteria

Bacteria are the most dominant microorganisms in both naturally fermented foods or foods fermented by the use of starter cultures. Among the bacteria, lactic acid bacteria are commonly associated with acidic fermented foods, while non-LAB bacteria such as *Bacillus*, micrococcaceae, *Bifidobacterium, Brachybacterium, Brevibacterium,* and *Propionibacterium* etc., are also involved in food fermentation, frequently as minor or secondary groups.

1.4.1.1 Lactic Acid Bacteria

Lactic acid bacteria are Gram-positive, catalase-negative bacteria that produce large amounts of lactic acid. The bacterial groups that make up the LAB are among the most familiar to humans, because of their association with the human environment, and with a wide range of naturally fermented dairy products, grain crops, vegetables, and so on. The LAB comprise a large bacterial group consisting of about 380 species in 40 genera of 6 families, belonging phylogenetically to the order *Lactobacillales* within the phylum *Firmicutes* (Stiles and Holzapfel 1997). Common genera of the LAB isolated from various fermented foods of the world are *Alkalibacterium, Carnobacterium, Enterococcus, Lactococcus, Lactobacillus, Leuconostoc, Oenococcus, Pediococcus, Streptococcus, Tetragenococcus, Vagococcus*, and *Weissella* (Carr et al. 2002, Salminen et al. 2004, MetaMicrobe.com/Lactic Acid Bacteria 2013).

1.4.1.2 Non-Lactic Acid Bacteria

Bacillus is reported from the alkaline-fermented foods of Asia and Africa (Parkouda et al. 2009). Species of *Bacillus* present in fermented foods mostly soybean-based foods are *B. amyloliquefaciens, B. circulans, B. coagulans, B. firmus, B. licheniformis, B. megaterium, B. pumilus, B. subtilis, B. subtilis* variety *natto* and *B. thuringiensis* (Kiers et al. 2000, Kubo et al. 2011), while strains of *B. cereus* have been isolated from the fermentation of *Prosopis africana* seeds for the production of *okpehe* in Nigeria (Oguntoyinbo et al. 2007). Some strains of *B. subtilis* produce λ-polyglutamic acid (PGA) which is an amino acid polymer commonly present in Asian fermented soybean foods giving the characteristic sticky texture to the product (Urushibata et al. 2002, Meerak et al. 2007, Nishito et al. 2010).

Species of *Bifidobacterium, Brachybacterium, Brevibacterium,* and *Propionibacterium* have been isolated from cheese and other fermented milks (Bourdichon et al. 2012). Several species of *Kocuria, Micrococcus,* and *Staphylococcus* have been reported from fermented milk products, fermented sausages and meat and fish products (Wu et al. 2000, Martín et al. 2006, Coton et al. 2010). *Enterobacter cloacae, Klebsiella pneumoniae, K. pneumoniae* subsp. *ozaenae, Haloanaerobium, Halobacterium, Halococcus, Propionibacterium, Pseudomonas*, and so on, are also present in many fermented foods (Tamang 2010b). Species of *Arthrobacter* and *Hafnia* are involved in meat fermentation (Bourdichon et al. 2012).

1.4.2 Yeasts

The role of yeasts in food fermentation is to ferment sugar, produce secondary metabolites, inhibit growth of mycotoxin-producing molds and display several enzymatic activities such as lipolytic, proteolytic, pectinolytic, glycosidasic and urease activities (Aidoo et al. 2006, Romano et al. 2006). Genera of yeasts reported from fermented foods, alcoholic beverages and nonfood mixed amylolytic starters are *Brettanomyces, Candida, Cryptococcus, Debaryomyces, Dekkera, Galactomyces, Geotrichum, Hansenula, Hanseniaspora, Hyphopichia, Issatchenkia, Kazachstania, Kluyveromyces, Metschnikowia, Pichia, Rhodotorula, Rhodosporidium, Saccharomyces,* *Saccharomycodes, Saccharomycopsis, Schizosaccharomyces, Sporobolomyces, Torulaspora, Torulopsis, Trichosporon, Yarrowia*, and *Zygosaccharomyces* (Watanabe et al. 2008, Tamang and Fleet 2009, Kurtzman et al. 2011, Lv et al. 2013).

1.4.3 Fungi

The major roles of fungi, mostly filamentous molds, in fermented foods and alcoholic beverages are the production of intra- and extracellular proteolytic and lipolytic enzymes that highly influence the flavor and texture of the product, and also the degradation of antinutritive factors improving bioavailability of minerals (Josephsen and Jespersen 2004, Aidoo and Nout 2010). Species of *Actinomucor, Amylomyces, Aspergillus, Monascus, Mucor, Neurospora, Penicillium, Rhizopus*, and *Ustilago* are reported from many fermented foods, Asian nonfood amylolytic starters and alcoholic beverages (Hesseltine 1991, Nout and Aidoo 2002).

1.4.4 Pathogenic Contaminants

About 80% of fermented foods are produced by natural fermentation and may contain functional, nonfunctional, and pathogenic microorganisms during initial fermentation. Pathogenic bacteria commonly reported for fermented foods are *Escherichia coli, Listeria monocytogenes, Yersinia enterocolitica, Bacillus cereus, Clostridium botulinum*, and so on (Lindqvist and Lindblad 2009, Rossi et al. 2011).

1.4.5 Gut Microflora

The human gastrointestinal tract (GIT) houses over 10^{14} microbial cells with over 1000 diverse bacterial types, mostly in the colon (Lepage et al. 2012, Purchiaroni et al. 2013). Colonization of the gut is initiated before birth following ingestion of microbe-containing amniotic fluid by the fetus (Mshvildadze and Neu 2010, Aagaard et al. 2014). The majority of bacteria in the adult gut are nonsporing anaerobes, the most numerically predominant of which include species of *Bacteroides, Bifidobacterium, Eubacterium, Clostridium, Lactobacillus, Fusobacterium*, and various Gram-positive cocci and bacteria that are present in lower numbers include *Enterococcus* spp., Enterobacteriaceae, methanogens, and dissimilatory sulfate-reducing bacteria (Wallace et al. 2011). Microorganisms colonize different parts of GIT and bacterial population density varies along the GIT (Romano-Keeler et al. 2014). The GIT is one of the most complex ecosystems of microorganisms ranging from bacteria (mostly LAB), archaea (e.g., methanogens), and eukarea (fungi, helminthes, and protozoa) as well as viruses (Mitsuoka 1992, Holzapfel et al. 1997, Norman et al. 2014). In healthy adults, 80% of the identified fecal microbiota belong to four dominant phyla: the Gram-negative *Bacteroides* and *Proteobacteria* and the Gram-positive *Actinobacteria* and *Firmicutes* which include at least 17 families, corresponding to no less than 1250 different species of bacteria (Schuijt et al. 2013). The composition and distribution of gut microbiota (Purchiaroni et al. 2013) are as follows: in the stomach (*Lb. reuteri, Lb. delbrueckii, Lb. gastricus, Lb. antri*), in the small intestine (*Lb. reuteri, Lb. bulgaricus, Lb. acidophilus, Enterococcus avium, Ent. dispar, Ent. durans, Ent. faecalis, Ent. faecium, Ent. flavescens, Ent. gallinarum, Ent. hirae, Ent. mundtii, Ent. raffinosus*), and in the large intestine (*Ent. faecalis, Bacteroides, Bifidobacterium, Eubacterium, Peptococcurs, Clostridium, Lactobacillus*).

1.5 Types of Fermented Foods

The major groups of substrates-based fermented foods are as follows:

1. Fermented milk foods
2. Fermented cereal foods
3. Fermented vegetable foods
4. Fermented soybean and non-soybean foods
5. Fermented meat products
6. Fermented fish products
7. Fermented root/tuber products
8. Fermented beverages and Asian amylolytic starters
9. Miscellaneous fermented products (fermented tea, cocoa, vinegar, *nata, pidan*, etc.)

1.5.1 Fermented Milks

Fermented milks (Table 1.1) are classified into two major groups based on the presence of dominant microorganisms: (i) lactic fermentations which are dominated by species of LAB, and consist of the thermophilic type (e.g., yogurt, Bulgarian buttermilk), probiotic type (acidophilus milk, yakult, bifidus milk), and the mesophilic type (e.g., natural fermented milk, cultured milk, cultured cream, cultured buttermilk); and (ii) fungal-lactic fermentations where LAB and yeasts species cooperate to generate the final product and consist of alcoholic milks (e.g., *kefir, koumiss*, acidophilus-yeast milk), and moldy milks (e.g., *viili*) (Mayo et al. 2010). Starter cultures in milk fermentation are of two types depending on the principal function, primary cultures to participate in the acidification, and secondary cultures for flavor, aroma, and maturing activities (Topisirovic et al. 2006). The main species involved as primary cultures in milk fermentation are *Lactococcus lactis* subsp. *cremoris, Lc. lactis* subsp. *lactis, Lactobacillus delbrueckii* subsp. *delbrueckii, Lb. delbrueckii* subsp. *lactis, Lb. helveticus, Leuconostoc* spp., and *Streptococcus thermophilus* (Parente and Cogan 2004). Secondary cultures used in cheese making are *Brevibacterium linens, Propionibacterium freudenreichii, Debaryomyces hansenii, Geotrichum candidum, Penicillium camemberti*, and *P. roqueforti* for the development of flavor and texture during the ripening of cheese (Coppola et al. 2006, Quigley et al. 2011). Besides primary and secondary cultures, some nonstarter lactic acid bacteria (NSLAB) microbiota are usually present in high numbers which include *Enterococcus durans, Ent. faecium, Lb. casei, Lb. plantarum, Lb. salivarius*, and *Staphylococcus* spp. (Briggiler-Marcó et al. 2007). Yogurt is a widely consumed highly nutritious fermented milk as a coagulated milk product resulting from the fermentation of milk by *Strep. thermophilus* and *Lb. delbrueckii* subsp. *bulgaricus* (formerly *Lb. bulgaricus*) (Tamime and Robinson 2007). *Lb. acidophilus, Lb. casei, Lb. rhamnosus, Lb. gasseri, Lb. johnsonii*, and *Bifidobacterium* spp., are among the most common adjunct cultures in yogurt fermentation (Guarner et al. 2005). Fermented milk products that are manufactured using starter cultures containing yeasts include acidophilus-yeast milk, *kefir, koumiss*, and *viili* (de Ramesh et al. 2006). *Lb. acidophilus, Lb. amylovorus, Lb. crispatus, Lb. gallinarum, Lb. gasseri,* and *Lb. johnsonii* are reported from acidophilus milk (Berger et al. 2007).

Natural fermented milks are one of the oldest methods of milk fermentation using raw or boiled milk to ferment spontaneously or by using the back-slopping method (Robinson and Tamime 2006). In back-slopping, a part of a precious batch of a fermented product is used to inoculate the new batch

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Table 1.1 Some Common and Uncommon Ethnic Fermented Milk Products of the World

Product	*Substrate*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Acidophilus milk	Cow milk	Acidic, sour, drink	Species of *Lactobacillus, Lactococcus*	Russia, East Europe, Greece, Turkey, North America, Scandinavia	Mayo et al. (2010)
Airag	Mare or camel milk	Acidic, sour, mild alcoholic, drink	*Lb. helveticus, Lb. kefiranofaciens, Bifidobacterium mongoliense, Kluyveromyces marxianus*	Mongolia	Watanabe et al. (2008, 2009b)
Ayib	Goat milk		*Canida* sp., *Saccharomyces* sp., *Lactobacillus* sp., *Leuconostoc* sp.	East and Central Africa	Odunfa and Oyewole (1997)
Biruni	Cow/camel milk	Acidic, semi-liquid, drink	LAB	Sudan	Jung (2012)
Butter	Animal milk	Soft paste, butter	LAB	Worldwide	Mayo et al. (2010)
Buttermilk		Acid fermented butter milk	*Lb. bulgaricus*	Bulgaria	Mayo et al. (2010)
Cheese	Animal milk	Soft or hard, solid; side dish, salad	*Lc. lactis* subsp. *cremoris, Lc. lactis* subsp. *lactis, Lb. delbrueckii* subsp. *delbrueckii, Lb. delbrueckii* subsp. *lactis, Lb. helveticus, Lb. casei, Lb. plantarum, Lb. salivarius, Leuconostoc* spp., *Strep. thermophilus, Ent. durans, Ent. faecium,* and *Staphylococcus* spp., *Brevibacterium linens, Propionibacterium freudenreichii, Debaryomyces hansenii, Geotrichum candidum, Penicillium camemberti, P. roqueforti.*	Worldwide	Parente and Cogan (2004), Quigley et al. (2011)

Chhu	Yak/cow milk	Cheese like product, curry, soup	*Lb. farciminis, Lb. brevis, Lb. alimentarius, Lb. salivarius, Lact. lactis, Saccharomycopsis* sp., *Candida* sp.	India, Nepal, Bhutan, China (Tibet)	Dewan. and Tamang (2006)
Chhurpi (hard)	Yak/cow milk	Chewable milk, masticator	*Lb. farciminis, Lb. casei, Lb. biofermentans, W. confusus*	India, Nepal, Bhutan, China (Tibet)	Tamang (2010a)
Chhurpi (soft)	Yak/cow milk	Cheese-like product, soup, curry, pickle	*Lb. farciminis, Lb. paracasei, Lb. biofermentans, Lb.plantarum, Lb. curvatus, Lb. fermentum, Lb. alimentarius, Lb. kefir, Lb. hilgardii, W. confusus, Ent. faecium, Leuc. mesenteroides*	India, Nepal, Bhutan, China (Tibet)	Tamang et al. (2000)
Dahi	Cow/buffalo milk, starter culture	Curd, savory	*Lb. bifermentans, Lb. alimentarius, Lb. paracasei, Lact. lactis, Strep. cremoris, Strep. lactis, Strep. thermophilus, Lb.bulgaricus, Lb. acidophilus, Lb. helveticus, Lb. cremoris, Ped. pentosaceous, P. acidilactici, W. cibara, W. paramesenteroides, Lb. fermentum, Lb. delbrueckii* subsp. *indicus, Saccharomycopsis* sp., *Candida* sp.	India, Nepal, Sri Lanka, Bangladesh, Pakistan	Harun-ur-Rashid et al. (2007), Patil et al. (2010)
Ergo	Milk	Acid fermented butter milk	*Lactobacillus* sp., *Lactococcus* sp.	Ethiopia	Steinkraus (1996)
Filmjölk	Cow milk	Less-sour than yoghurt, yoghurt-like	*Lc. lactis* and *Leuc. mesenteroides*	Sweden	Kosikowski and Mistry (1997)
Gariss	Camel milk	Acidic, liquid, refreshing beverage	LAB	Sudan	Akabanda et al. (2013)
Gheu/ghee	Cow milk	Soft, oily mass, solid, butter	*Lc. lactis* subsp. *lactis, Lc. lactis* subsp. *cremoris*	India, Nepal, Bhutan, Bangladesh, Pakistan	Tamang (2010a)

(*Continued*)

Table 1.1 (*Continued*) Some Common and Uncommon Ethnic Fermented Milk Products of the World

Product	*Substrate*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Kefir	Goat, sheep, cow	Alcoholic fermented milk, effervescent milk	*Tor. holmii, Tor. delbruechii, Lb. brevis, Lb. caucasicus,Strep. thermophilus, Lb. bulgaricus, Lb. plantarum, Lb. casei, Lb. brevis*	Russia	Bernardeau et al. (2006)
Kesong Puti, Keso, Kesiyo	Carabao's (buffalo) milk or cow carabao's milk, salt, Abomasal extracts coagulant, starter	White cheese, soft cheese	*Lb. helveticus, Lact. lactis, Lb. rhamnosus, Leuc. mesenteroides, Lb. acidophilus, Lb. plantarum, Lb. brevis, Lb. curvatus*	Philippines	Kisworo (2003)
Kishk	Milk, wheat	Fermented milk wheat mix, drink	*Lb. plantarum, Lb. brevis, Lb. bulgaricus, Lb. casei, Strep. thermophilus*	Egypt	Bernardeau et al. (2006)
Kurut	Yak milk	Naturally fermented milk, drink	LAB	China	Sun et al. (2010)
Kushuk	Milk, wheat	Fermented milk wheat mix, drink	*Lb. plantarum, Lb. brevis*	Iraq	Bernardeau et al. (2006)
Koumiss	Milk	Acid fermented milk, drink	*Lb. bulgaricus, Torula* sp., *Lb. salivarius, Lb. buchneri, Lb. heveticus, Lb. plantarum, Lb. acidophilus*	Russia	Hao et al. (2010)
Laban rayeb	Milk	Acid fermented milk, yoghurt-like	*Lb. casei, Lb. plantarum, Lb. brevis, Lact. lactis, Sacch. kefir, Leuconostoc* sp.	Egypt	Bernardeau et al. (2006)

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Laban zeer	Milk	Acid fermented milk	*Lb. casei, Lb. plantarum, Lb. brevis, Lc. lactis, Lc. lactis*	Egypt	Bernardeau et al. (2006)
Lassi	Cow milk	Acidic, buttermilk, refreshing beverage	*Lb. Acidophilus, Strep. thermophilus*	India, Nepal, Bhutan, Bangladesh, Pakistan	Patidar and Prajapati (1998)
Långfil	Cow milk	Elastic texture, sour, yoghurt-like	LAB	Sweden	Tamime (2005)
Leben/Lben	Cow milk	Sour milk	*Candida* sp., *Saccharomyces* sp., *Lactobacillus* sp., *Leuconostoc* sp.,	North, East Central Africa	Odunfa and Oyewole (1997)
Liban-argeel	Sheep, goat, cow, buffalo milk	Acid fermented milk	LAB	Iraq	Bernardeau et al. (2006)
Maa	Yak milk	Mild-acidic, viscous, butter	LAB, yeasts	China (Tibet), India, Bhutan	Tamang (2010a)
Maziwa lala	Milk	Yoghurt-like	*Strep. lactis, Strep. thermophilus*	Kenya	Olasupo et al. (2010)
Mohi	Cow milk	Acidic, buttermilk, refreshing beverage	*Lb. alimentarius, Lc. lactis* subsp. *lactis, Lc. lactis* subsp. *cremoris; Saccharomycopsis* spp. and *Candida* spp.	Nepal, India, Bhutan	Dewan and Tamang (2007)
Mish	Cow/camel milk	Acidic, semi-liquid, refreshing beverage	LAB	Sudan, Egypt	Bernardeau et al. (2006)
Misti dahi (mishti doi, lal dahi, payodhi)	Buffalo/cow milk	Mild-acidic, thick-gel, sweetened curd, savory	*Strep. salivarius* subsp. *thermophilus, Lb. acidophilus, Lb. delbrueckii* subsp. *bulgaricus, Lc. lactis* subsp. *lactis, Sacch. cerevisiae.*	India, Bangladesh	Ghosh and Rajorhia (1990), Gupta et al. (2000)

(*Continued*)

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Table 1.1 (*Continued*) Some Common and Uncommon Ethnic Fermented Milk Products of the World

Product	*Substrate*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Nunu	Raw cow milk	Naturally fermented milk	*Lb. fermentum, Lb. plantarum, Lb. helveticus, Leuc. mesenteroides, Ent. faecium, Ent. italicus, Weissella confuse; Candida parapsilosis, C. rugosa, C. tropicalis, Galactomyces geotrichum, Pichia kudriavzevii, Sacch. cerevisiae*	Ghana	Akabanda et al. (2013)
Paneer	Buffalo or cow milk	Whey, soft, cheese-like product, fried snacks, curry	LAB	India, Nepal, Pakistan, Bangladesh, Middle East	Tamang (2012b)
Phrung	Yak milk	Mild-acidic, hard-mass like *chhurpi*, masticator	Unknown	India, China (Tibet)	Tamang (2010a)
Philu	Cow or yak milk, bamboo vessels	Cream like product, curry	*Lb. paracasei, Lb. bifermentans, Ent. faecium*	India, Nepal, Tibet (China)	Dewan and Tamang (2007)
Pheuja or suja	Tea-yak butter, salt	Salty with buttery flavor, liquid, Refreshing tea	Unknown	India, China (Tibet), Bhutan, Nepal	Tamang (2010a)
Rob	Cow, goat, sheep milk	Mild-acidic, savory	LAB	Sudan	Akabanda et al. (2013)
Shrikhand	Cow, buffalo milk	Acidic, concentrated sweetened viscous, savory	*Lc. lactis* subsp. *lactis, Lc. lactis* subsp. *diacetylactis, Lc. lactis* subsp. *cremoris, Strep. thermophilus, Lb. delbruecki* subsp. *Bulgaricus*	India	Aneja et al. (2002)

Somar	Yak or cow milk	Buttermilk	*Lb. paracasei, Lact. Lactis*	India, Nepal	Dewan and Tamang. (2007)
Sour milk kerbah	Milk	Acid fermented milk	*Lact. lactis, Sacch. kefir, Lb. casei, Lb. brevis, Lb. plantarum*	Egypt	Mayo et al. (2010)
Sua chua	Dried skim milk, starter, sugar	Acid fermented milk	*Lb. bulgaricus, Strep. thermophilus*	Vietnam	Alexandraki et al. (2013)
Shyow	Yak milk	Acidic, thick-gel viscous, curd-like, savory	LAB, yeasts	China (Tibet), Bhutan, India	Tamang (2010a)
Tarag	Cow, yak, goat milk	Acidic, sour, drink	*Lb. delbrueckii* subsp. *bulgaricus, Lb. helveticus, Strep. thermophilus, Sacch. cerevisiae, Issatchenkia orientalis, Kazachstania unispora*	Mongolia	Watanabe et al. (2008)
Viili	Cow milk	Thick and sticky, sweet taste, breakfast	*Lc. lactis* subsp. *lactis, Lc. lactis* subsp. *cremoris, Lc. lactis* subsp. *lactis* biovar. *Diacetylactis, Leuc. mesenteroides* subps. *cremoris, G. candidum, K. marxianus, P. fermentans*	Finland	Kahala et al. (2008)
Wara	Milk	Sweet taste, beverage	*Lc. lactis, Lactobacillus* sp.	West Africa	Olasupo et al. (2010)
Yoghurt	Animal milk	Acidic, thick-gel viscous, curd-like product, savory	*Strep. thermophilus, Lb. delbrueckii* subsp. *bulgaricus, Lb. acidophilus, Lb. casei, Lb. rhamnosus, Lb. gasseri, Lb. johnsonii, Bifidobacterium* spp.	Europe, Australia, America	Tamime and Robinson (2007)

(Josephsen and Jespersen 2004). Examples of naturally fermented milks are *dahi, lassi, misti dahi, srikhand, chhu, chhurpi, mohi, philu, shoyu, somar* (cow/buffalo/yak milk) of India, Nepal, Pakistan, Bhutan, and Bangladesh (Harun-ur-Rashid et al. 2007, Sarkar 2008, Patil et al. 2010, Tamang 2010a, Tamang et al. 2012), *kurut* of China (Sun et al. 2010), *aaruul, airag, byasulag, chigee, eezgii, tarag,* and *khoormog* of Mongolia (Watanabe et al. 2008, Takeda et al. 2011, Oki et al. 2014), *ergo* of Ethiopia, *kad, lben, laban, rayeb, zabady, zeer* of Morocco and Northern African and Middle East countries, *rob* (from camel milk), *biruni* (cow/camel milk), *mish* (cow/camel milk) of Sudan, *amasi* (*hodzeko, mukaka wakakora*) of Zimbabwe, *nunu* (from raw cow milk) of Ghana (Akabanda et al. 2013), *filmjölk* and *långfil* of Sweden (Mayo et al. 2010), *koumiss* or *kumis* or *kumys* or *kymys* of the Caucasian area (Wu et al. 2009).

Lc. lactis subsp. *cremoris,* and *Lc. lactis* subsp. *lactis* are found among the dominant microbiota along with other mesophilic lactobacilli (*Lb. casei/Lb. paracasei, Lb. fermentum, Lb. helveticus, Lb. plantarum,* and/or *Lb. acidophilus*), *Ent. faecium,* and species of *Leuconostoc* and *Pediococcus* in naturally fermented milks (Tamang et al. 2000, Mathara et al. 2004, Patrignani et al. 2006, Dewan and Tamang 2006, 2007, Yu et al. 2011, Akabanda et al. 2013). Yeasts present in naturally fermented milks are *Candida lusitaniae, C. parapsilosis, C. rugosa, C. tropicalis, Kluyveromyces* (*Kl.*) *marxianus, Sacch. cerevisiae, Galactomyces geotrichum, Pichia kudriavzevii*, and others (Gadaga et al. 2000, Dewan and Tamang 2006, Akabanda et al. 2013). *Koumiss* or *kumis* or *kumys* or *kymys* is a natural fermented dairy product of the Caucasian area. *Lb. casei, Lb. coryniformis, Lb. curvatus, Lb. helveticus, Lb. kefiranofaciens, Lb. kefiri, Lb. paracasei, Lb. plantarum, Lb. fermentum,* and *Leuc. mesenteroides* (Ying et al. 2004, Watanabe et al. 2008, Wu et al. 2009), *Lb. acidophilus, Lb. fermentum*, and *Lb. kefiranofaciens* (dominant LAB), *E. faecalis, Lc. lactis, Lb. buchneri, Lb. jensenii, Lb. kefiri, Lb. kitasatonis, Lb. paracasei, Leuc. mesenteroides*, and *Strep. thermophilus* (Hao et al. 2010), yeasts *Sacch. cerevisiae, Issatchenkia orientalis, Kazachstania unispora, Kl. marxianus, Pichia mandshurica* (Watanabe et al. 2008) were isolated from *koumiss*.

1.5.2 Fermented Cereal Foods

The well-documented fermented cereal foods of the world (Table 1.2) are sourdough of Europe, America, and Australia (de Vuyst et al. 2009), *selroti* of India and Nepal (Yonzan and Tamang 2009), *idli* of India and Sri Lanka (Sridevi et al. 2010), *dosa* of India and Sri Lanka (Soni et al. 1986), *mawè* and *gowé* of Benin (Vieira-Dalodé et al. 2007), *ben-saalga* of Burkino Faso and Ghana (Humblot and Guyot 2009), *kisra* of Sudan (Hamad et al. 1997), *kenkey* of Ghana (Oguntoyinbo et al. 2011), *togwa* of Tanzania (Mugula et al. 2003), *ting* of Botswana (Sekwati-Monang and Gänzle 2011), *ogi* and *kunu-zaki* of Nigeria (Oguntoyinbo et al. 2011), and *tarhana* of Turkey, Cyprus and Greece (Sengun et al. 2009). Cereal fermentation is characterized by a complex microbial ecosystem, mainly represented by the species of LAB and yeasts (Corsetti and Settanni 2007), whose fermentation confers to the resulting bread its characteristic features such as palatability and high sensory quality (Blandino et al. 2003). The species of *Enterococcus, Lactococcus, Lactobacillus, Leuconostoc, Pediococcus, Streptococcus*, and *Weissella* are commonly associated with cereal fermentation (Guyot 2010). A native strain of *Sacch. cerevisiae* is the principal yeast of most bread fermentations (Hammes et al. 2005). Other non-*Saccharomyces* yeasts are also significant in many cereal fermentations which include *Candida, Debaryomyces, Hansenula, Pichia, Trichosporon, Yarrowia* (Foschino et al. 2004, Veinocchi et al. 2006). *Lb. plantarum, Lb. panis, Lb. sanfrancisensis, Lb. pontis, Lb. brevis, Lb. curvatus, Lb. sakei, Lb. alimentarius, Lb. fructivorans, Lb. paralimentarius, Lb. pentosus, Lb. spicheri, Lb. crispatus, Lb. delbrueckii, Lb. fermentum, Lb. reuteri, Lb. acidophilus, Lc. lactis, Leuc. mesenteroides, Ped. pentosaceus, W. confuse*. The yeasts

Table 1.2 Some Common and Uncommon Ethnic Fermented Cereal Foods of the World

Product	*Raw Material/ Substrate*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Abreh	Sorghum	Solid state and submerged	*Lb. plantarum*	Sudan	Odunfa and Oyewole (1997)
Aliha	Maize, sorghum	Nonalcoholic beverage	LAB	Ghana, Togo, Benin	Odunfa and Oyewole (1997)
Ambali	Millet, rice	Acidic, pan cake Shallow-fried, staple	LAB	India	Tamang (2010a)
Ang-kak	Red rice	Colorant	*Monascus purpureus*	China, Taiwan, Thailand, Phillipines	Steinkraus (1996)
Banku	Maize and cassava	Staple food	*Lactobacillus* sp., yeasts	Ghana	Campbell-Platt (1987)
Bahtura	Wheat flour	Deep-fried bread	LAB, yeasts	India	Campbell-Platt (1987)
Boza	Cereals	Sour refreshing liquid	*Lactobacillus* sp., *Lactococcus* sp., *Pediococcus* sp., *Leuconostoc* sp., *Sacch. cerevisiae*	Bulgaria, Balkan	Blandino et al. (2003)
Burukutu	Sorghum and cassava	Creamy, liquid, drink	*Sacch. cerevisiae, Sacch. chavelieri, Leuc. mesenteroides, Candida* sp., *Acetobacter* sp.	Nigeria	Odunfa and Oyewole (1997), Kolawole et al. (2013)
Busa	Maize, sorghum, millet	Submerged	*Sacch. cerevisiae, Schizosacchromyces pombe, Lb. plantarum ,Lb. helveticus, Lb. salivarius, Lb. casei, Lb. brevis, Lb. buchneri, Leuc. mesenteroides, Ped. damnosus*	East Africa, Kenya	Odunfa and Oyewole (1997), Blandino et al. (2003)

(*Continued*)

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Table 1.2 (*Continued*) Some Common and Uncommon Ethnic Fermented Cereal Foods of the World

Product	*Raw Material/ Substrate*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Ben-saalga	Pearl millet	Weaning food	*Lactobacillus* sp., *Pediococcus* sp., *Leuconostoc* sp., *Weissela* sp., yeasts	Burkina Faso, Ghana	Tou et al. (2007)
Chilra	Wheat, barley, buckwheat	Staple	LAB, *Sacch. cerevisiae*	India	Thakur et al. (2004)
Dégué	Millet	Condiment	*Lb. gasseri, Lb. fermentum, Lb. brevis, Lb. casei, Enterococcus* sp.	Burkina Faso	Abriouel et al. (2006)
Dosa	Rice and black gram	Thin, crisp pancake, Shallow-fried, staple	*Leuc. mesenteroides, Ent. faecalis, Tor. candida, Trichosporon pullulans*	India, Sri Lanka, Malaysia, Singapore	Soni et al. (1986)
Enjera/Injera	Tef flour, wheat	Acidic, sourdough, leavened, pancake-like bread, staple	*Lb. pontis, Lb. plantarum, Leuc. mesenteroides, Ped. cerevisiae, Sacch. cerevisiae, Cand. glabrata*	Ethiopia	Olasupo et al. (2010)
Gowé	Maize	Intermediate product used to prepare beverages, porridges	*Lb. fermentum, Lb. reuteri, Lb. brevis, Lb. confusus, Lb. curvatus, Lb. buchneri, Lb. salivarius, Lact. lactis, Ped. pentosaceus, Ped. acidilactici, Leuc. mesenteroides; Candida tropicalis, C. krusei, Kluyveromyces marxianus*	Benin	Vieira-Dalodé et al. (2007), Greppi et al. (2013a)
Hakua	Rice	Strong off-flavor, therapeutic uses	Unknown	Nepal, India	Tamang (2005)
Hopper	Rice, coconut water	Steak-baked, pancake, staple	*Sacch. cerevisiae*, LAB	Sri Lanka	Steinkraus (1996)
Hussuwa	Sorghum	Cooked dough	*Lb. fermentum, Ped. acidilactici, Ped. pentosaceus*, Yeasts	Sudan	Yousif et al. (2010)

Huitlacoche or 'maize mushroom'	cobs of pre-harvest maize	Large fruiting body edible, condiment	*Ustilago maydis*	Mexico	Alexandraki et al. (2013)
Hulumur	Sorghum, rice, millet	Nonalcoholic drink	*Leuc. mesenteroides, Lb. Plantarum, Lactobacillus* sp.	Sudan, Turkey	Campbell-Platt (1987)
Idli	Rice, blackgram dhal or other dehusked pulses	Mild-acidic, soft, moist, spongy pudding; staple, breakfast	*Leuc. mesenteroides, Lb. delbrueckii, Lb. fermenti, Lb. coryniformis, Ped. acidilactis, Ped. cerevisae, Streptococcus* sp., *Ent. faecalis, Lact. lactis, B. amyloliquefaciens, Cand. cacaoi, Cand. fragicola, Cand. glabrata, Cand. kefyr, Cand. pseudotropicalis, Cand. sake, Cand. tropicalis, Deb. hansenii, Deb. tamarii, Issatchenkia terricola, Rhiz. graminis, Sacch. cerevisiae, Tor. candida, Tor. holmii*	India, Sri Lanka, Malaysia, Singapore	Steinkraus et al. (1967), Sridevi et al. (2010)
Jalebi	Wheat flour	Crispy sweet, donut-like, deep-fried, snacks	*Sacch. Bayanus, Lb. fermentum, Lb. buchneri, Lact. lactis, Ent. faecalis, Sacch. cerevisiae*	India, Nepal, Pakistan	FAO (1999)
Kenkey	Maize	Acidic, solid, steamed dumpling, staple	*Lb. plantarum, Lb. brevis, Ent. cloacae, Acinetobacter* sp., *Sacch. cerevisiae, Cand. mycoderma*	Ghana	Odunfa and Oyewole (1997), Oguntoyinbo et al. (2011)
Khanom-jeen	Rice	Noodle, staple	*Lactobacillus* sp., *Streptococcus* sp., *Rhizopus* sp., *Mucor* sp.	Thailand	Blandino et al. (2003)
Khamak (Kao-mak)	Glutinous rice, *Look-pang* (starter)	Dessert	*Rhizopus* sp., *Mucor* sp., *Penicillum* sp., *Aspergillus* sp., *Endomycopsis* sp., *Hansenula* sp., *Saccharomyces* sp.	Thailand	Alexandraki et al. (2013)

(*Continued*)

Table 1.2 (*Continued*) Some Common and Uncommon Ethnic Fermented Cereal Foods of the World

Product	*Raw Material/ Substrate*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Kichudok	Rice	Steamed cake, side dish	*Leuc. mesenteroides*, *Ent. faecalis*, *Saccharomyces* sp.	Korea	Von Mollendorff (2008)
Kunu-zaki	Maize, sorghum, millet	Mild-acidic, viscous, porridge, staple	*Lb. plantarum*, *Lb. pantheris*, *Lb. vaccinostercus*, *Corynebacterium* sp., *Aerobacter* sp., *Cand. mycoderma*, *Sacch. cerevisiae*, *Rhodotorula* sp., *Cephalosporium* sp., *Fusarium* sp., *Aspergillus* sp., *Penicillium* sp.	Nigeria	Oguntoyinbo et al. (2011)
Kisra	Sorghum	Thin pancake bread, staple	*Ped. pentosaceus*, *Lb. confusus*, *Lb. brevis*, *Lactobacillus* sp., *Erwinia ananas*, *Klebsiella pneumoniae*, *Ent. cloacae*, *Cand. intermedia*, *Deb. hansenii*, *Aspergillus* sp., *Penicillium* sp., *Fusarium* sp., *Rhizopus* sp.	Sudan	Mohammed et al. (1991), Hamad et al. (1997)
Kishk	Wheat, milk	Refreshing beverage	*Lb. plantarum*, *Lb. brevis*, *Lb. casei*, *B. subtilis*, Yeasts	Egypt	Blandino et al. (2003)
Koko	Maize	Porridge	*Ent. clocae*, *Acinetobacter* sp., *Lb. plantarum*, *Lb. brevis*, *Sacch. cerevisiae*, *Cand. mycoderma*	Ghana	Blandino et al. (2003)
Kunu-zaki	Maize (white and yellow), red sorghum	Mild, sour liquid/ porridge, staple	*W. confusa*, *Strep. lutetiensis*, *Strep. gallolyticus* subsp. *macedonicus*,	West Africa, Nigeria	Olasupo et al. (2010)
Lao-chao	Rice	Paste, soft, juicy, glurinous desert	*Rhiz. oryzae*, *Rhiz. Chinensis*, *Chlamydomucor oryzae*, *Sacchromycopsis* sp.	China	Blandino et al. (2003)

Maheu	Maize, sorghum, millet	Refreshing beverage	*Lb. delbrueckii*	South Africa	Steinkraus (2004)
Mahewu	Maize	Refreshing beverage	*Lb. delbruchi, Lact. lactis*	South Africa	Blandino et al. (2003)
Mawè	Maize	Intermediate product used to prepare beverages, porridges	*Lb. fermentum, Lb. reuteri, Lb. brevis, Lb. confusus, Lb. curvatus, Lb. buchneri, Lb. salivarius, Lact. lactis, Ped. pentosaceus, Ped. acidilactici, Leuc. mesenteroides; Candida glabrata, Sacch. cerevisiae, Kluyveromyces marxianus, Clavispora lusitaniae*	Benin, Togo	Hounhouigan et al. (1993), Greppi et al. (2013a,b)
Masvusvu	Maize	Refreshing beverage	LAB	Zimbabwe	Alexandraki et al. (2013)
Marchu	Wheat flour	Baked bread	Unknown	India, Pakistan	Tamang (2010a)
Mbege	Maize, sorghum, millet	Submerged	*Sacch. cerevisiae, Schizosaccharomyces pombe, Lb. plantarum, Leuc. mesenteroides*	Tanzania	Odunfa and Oyewole (1997)
Me	Rice	Acidic, sour, condiment	LAB	Vietnam	Alexandraki et al. (2013)
Minchin	Wheat gluten	Solid, condiment	*Paceilomyces* sp., *Aspergilus* sp., *Cladosporium* sp., *Fusarium* sp., *Syncephalastum* sp., *Penicillium* sp., *Trichothecium* sp.	China	Blandino et al. (2003)
Mungbean starch	Mungbean	Fermented noodle	*Leuc. mesenteroides*	Thailand	Alexandraki et al. (2013)

(*Continued*)

Health Benefits of Fermented Foods and Beverages

Table 1.2 (*Continued*) Some Common and Uncommon Ethnic Fermented Cereal Foods of the World

Product	*Raw Material/ Substrate*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Naan	Wheat flour	Leaved bread, baked	*Sacch. cerevisiae*, LAB	India, Pakistan, Afghanistan	Batra (1986)
Ogi	Maize, sorghum, millet	Mild-acidic, viscous, porridge, staple	*Lb. plantarum*, *Lb. pantheris*, *Lb. vaccinostercus*, *Corynebacterium* sp., *Aerobacter* sp., *Candida krusei*, *Clavispora lusitaniae*, *Sacch. cerevisiae*, *Rhodotorula* sp., *Cephalosporium* sp., *Fusarium* sp., *Aspergillus* sp., *Penicillium* sp.	Nigeria	Odunfa and Oyewole (1997), Greppi et al. (2013a)
Perkarnaya	Rye	Acidic, aerated bread	Yeasts, LAB	Russia	Alexandraki et al. (2013)
Pito	Maize, sorghum, millet	Submerged	*Geotrichum candidum*, *Lactobacillus* sp., *Candida* sp.	West Africa	Odunfa and Oyewole (1997)
Poto poto (Gruel)	Maize	Slurry	*Lb. gasseri*, *Lb. plantarum/ paraplantarum*, *Lb. acidophilus*, *Lb. delbrueckii*, *Lb. reuteri*, *Lb. casei*, *Bacillus* sp., *Enterococcus* sp., yeasts	Congo	Abriouel et al. (2006)
Pozol	Maize	Mild-acidic, thick viscous, porridge, staple	*Lactobacillus* sp., *Leuconostoc* sp., *Candida* sp., *Enterobacteriaceae*, *B. cereus*, *Paracolobactrum aerogenoides*, *Agrobacterium azotophilum*, *Alkaligenes pozolis*, *E. coli* var. *napolitana*, *Pseudomonas mexicana*, *Kleb. pneumoniae*, *Saccharomyces* sp., molds	Mexico	FAO (1998)
Pumpernickel	Rye	Acidic, full-grain, aerated bread; long shelf-life	Yeasts, LAB, as for rye sourdough	Switzerland, Germany	Alexandraki et al. (2013)

Puto	Rice	Steamed cake, breakfast	*Leuc. mesenteroides, Ent. faecalis, Ped. cerevisiae*, yeasts	Philippines	Steinkraus (1996)
Rabadi	Buffalo or cow milk and cereals, pulses	Mild-acidic, thick slurry-like product	*Ped. acidilactici, Bacillus* sp., *Micrococcus* sp.; Yeasts	India, Pakistan	Ramakrishnan (1979), Gupta et al. (1992)
Sourdough bread	Rye	Sandwich, bread	*Lb. pontis* and *Lb. panis, Lb. amylovorus, Lb. acidophilus, Lb. crispatus, Lb. delbrueckii, Lb. fermentum, Lb. reuteri, Sacch. cerevisiae, Issatchenkia orientalis*	Germany, Northern Europe	Iacumin et al. (2009)
San Francisco	(Rye), mainly wheat	Mild-acidic, leavened bread	*Lb. sanfrancisensis, Lb. alimentarius, Lb. brevis, Lb. fructivorans, Lb. paralimentarius, Lb. pentosus, Lb. plantarum, Lb. pontis, Lb. spicheri, Leuc. mesenteroides, W. confusa*	USA	Gänzle et al. (1998)
Seera	Wheat grains	Dried, sweet dish	Unknown	India, Pakistan	Thakur et al. (2004)
Selroti	Rice-wheat flour-milk	Pretzel-like, deep-fried bread, staple	*Leuc. mesenteroides, Ent. faecium, Ped. pentosaceus* and *Lb. curvatus, Sacch. cerevisiae, Sacch. kluyveri, Deb. hansenii, P. burtonii, Zygosaccharomyces rouxii*	India, Nepal, Bhutan	Yonzan and Tamang (2010, 2013)
Siddu	Wheat flour, opium seeds, walnut	Steamed bread, oval-shaped, staple	*Sacch. cerevisiae, Cand. valida*	India	Thakur et al. (2004)
Sourdough bread	Rye, wheat	Mild-acidic, leavened bread	*Lb. sanfranciscensis, Lb. alimentarius, Lb. buchneri, Lb. casei, Lb. delbrueckii, Lb. fructivorans, Lb. plantarum, Lb. reuteri, Lb. johnsonii, Cand. humili, Issatchenkia orientalis*	America, Europe, Australia	de Vuyst et al. (2009)

(*Continued*)

Health Benefits of Fermented Foods and Beverages

Table 1.2 (*Continued*) Some Common and Uncommon Ethnic Fermented Cereal Foods of the World

Product	*Raw Material/ Substrate*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Tapai Pulut	Glutinous rice, *Ragi*		*Chlamydomucor* sp., *Endomycopsis* sp., *Hansenula* sp.	Malaysia	Steinkraus (1996)
Tape Ketan	Glutinous rice, *Ragi*		*Thizopus* sp., *Chlamydomucor* sp., *Candida* sp., *Endomycopsis* sp., *Saccharomyces* sp.	Indonesia	Steinkraus (1996)
Tepache	Maize, pineapple, apple or orange		*B. subtilis*, *B. graveolus* and the yeasts, *Tor. insconspicna*, *Sacch. cerevisiae* and *Cand. queretana*	Mexico	FAO (1998)
Ting	Sorghum	Sour taste	LAB	Botswana	Sekwati-Monang and Gänzle (2011)
Togwa	Cassava, maize, sorghum, millet	Fermented gruel or beverage	*Lb. brevis, Lb. cellobiosus, Lb. fermentum, Lb. plantarum and Ped. pentosaceus, Candida pelliculosa, C. tropicalis, Issatchenkia orientalis, Sacch. cerevisiae*	Tanzania	Mugula et al. (2003)
Tarhana	Sheep milk, wheat	Mild-acidic, sweet-sour, soup or biscuit	*Lb. bulgaricus, Strep. thermophilus,* yeasts	Cyprus, Greece, Turkey	Karagozlu et al. (2008)
Taotjo	Wheat, rice, soybeans	Semi-solid food, condiment	*Asp. oryzae*	East Indies	Blandino et al. (2003)
Uji	Maize, sorghum, millet, cassava flour	Acidic, sour, porridge, staple	*Leuc. mesenteroides, Lb. plantarum*	Kenya, Uganda, Tanzania	Odunfa and Oyewole (1997)

Sacch. cerevisiae, Sacch. exiguus, Candida humilis, C. milleri, Issatchenkia orientalis were isolated from sourdough (Iacumin et al. 2009, Weckx et al. 2010). Gluten-free sourdough was prepared from buckwheat and/or teff flours using *Ped. pentosaceus, Leuc. holzapfelii, Lb. gallinarum, Lb. vaginalis, Lb. sakei, Lb. graminis, W. cibaria* (Moroni et al. 2011).

1.5.3 Fermented Vegetable Products

People eat plants, both domesticated and wild, preparing them according to a variety of recipes. Perishable and seasonal leafy vegetables, radish, cucumbers including young edible tender bamboo shoots are traditionally fermented into edible products using the indigenous knowledge of biopreservation. Mostly species of *Lactobacillus* and *Pediococcus*, followed by *Leuconostoc, Weisella, Tetragenococcus*, and *Lactococcus* (Watanabe et al. 2009a, Savadogo et al. 2011) have been isolated from various fermented vegetable foods of the world (Table 1.3). Species of LAB present in Korean *kimchi* are *Lc. lactis, Lb. brevis, Lb. curvatus, Lb. plantarum, Lb. sakei* subsp. *sakei, Luec. citreum, Leuc. gasicomitatum, Leuc. gelidum, Leuc. kimchii, Leuc. mesenteroides* subsp. *mesenteroides, Ped. pentosaceus, Weissella confusa, W. kimchii*, and *W. koreensis* (Shin et al. 2008, Nam et al. 2009, Park et al. 2010, Jung et al. 2011). A few species of non-LAB and yeasts were also reported from *kimchi* which included species of *Halococcus, Haloterrigena, Candida, Kluyveromyces, Lodderomyces, Natrialba, Natronococcus, Pichia, Saccharomyces, Sporisorium*, and *Trichosporon* (Chang et al. 2008). The species of LAB reported from *sauerkraut* are *Lc. lactis* subsp. *lactis, Lb. brevis, Lb. curvatus Lb. plantarum, Lb. sakei, Leuc. fallax, Leuc. mesenteroides* and *Ped. pentosaceus* (Johanningsmeier et al. 2007, Plengvidhya et al. 2007). *Lb. brevis, Lb. casei, Lb. casei* subsp. *pseudoplantarum, Lb. fermentum, Lb. plantarum, Leuc. fallax, Ped. pentosaceus* constitute the native lactic flora in the Himalayan fermented vegetables such as *gundruk, sinki, goyang, khalpi, inziangsang* (Karki et al. 1983, Tamang et al. 2005, Tamang and Tamang 2007, 2010). *Lb. brevis, Lb. lactis, Lb. fermentum, Lb. pentosus, Lb. plantarum, Leuc. mesenteroides* and *Ped. pentosaceus* are the functional LAB in *pao cai* or *suan cai,* the naturally fermented vegetable products of China and Taiwan (Yan et al. 2008, Huang et al. 2009). A complex microbial community in the brines of fermented olives based on a culture-independent study consisted of LAB (*Lb. pentosus/Lb. plantarum, Lb. paracollinoides, Lb. vaccinostercus/Lb. suebicus* and *Pediococcus* sp.), both cultivable and uncultivable non-lactics (*Gordonia* sp./*Pseudomonas* sp., *Halorubrum orientalis, Halosarcina pallid, Sphingomonas* sp./*Sphingobium* sp./*Sphingopyxis* sp., *Thalassomonas agarivorans*) and yeasts (*Candida* cf. *apicola, Pichia* sp., *Pic. manshurica/Pic. galeiformis, Sacch. cerevisiae*) (Abriouel et al. 2011).

Sunki is an ethnic nonsalted and fermented vegetable product of Japan prepared from the leaves and stems of the red turnip (Wacher et al. 2010). *Lb. plantarum, Lb. brevis, Lb. buchneri, Lb. kisonensis, Lb. otakiensis, Lb. rapi, Lb. sunkii,E. faecalis, B. coagulans,* and *P. pentosaceus* have been isolated from *sunki* (Endo et al. 2008, Watanabe et al. 2009a). *Fu-tsai* and *suan-tsai* are the ethnic fermented mustard products of Taiwan prepared by the Hakka tribes eaten as soup, fried with shredded meat, or stewed with meat (Chao et al. 2009). *Ped. pentosaceus* and *Tetragenococcus halophilus* (Chen et al. 2006), *Lb. farciminis, Leuc. mesenteroides, Leuc. pseudomesenteroides, W. cibaria,* and *W. paramesenteroides* (Chao et al. 2009), *Lb. futsaii* (Chao et al. 2012) are isolated from *fu-tsai* and *suan-tsai*.

Ent. durans,Lb. brevis, Lb. coryniformis, Lb. curvatus, Lb. delbrueckii, Lb. plantarum, Lb. xylosus, Leuc. citreum, Leuc. fallax, Leuc. lactis, Leuc. mesenteroides, Ped. pentosaceus, Tetra. halophilus were reported from Indian fermented bamboo shoots (Tamang and Sarkar 1996, Tamang et al. 2008, Tamang and Tamang 2009, Tamang et al. 2012, Sonar and Halami 2014). Species of *B. cereus, B. pumilus, B. subtilis* and *Pseudomonas fluorescens* along with LAB were also isolated

Table 1.3 Some Common and Uncommon Ethnic Fermented Vegetable Products of the World

Product	*Substrate/Raw Materials*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Anishi	Taro leaves	Acidic, wet	LAB	India	Tamang (2010a)
Bastanga	Bamboo shoot	Acidic, soft	LAB	India	Tamang (2010a)
Burong mustala	Mustard	Acidic, wet	*Lb. brevis, Ped. cerevisiae*	Philippines	Rhee et al. (2011)
Cucumbers (pickles*)*	Cucumbers	Acidic, wet, pickle	*Leuc. mesenteroides, Ped. cerevisiae, Ped. acidilactici, Lb. plantarum, Lb. brevis*	Europe, USA, Canada	Vaughn (1985)
Dha muoi	Mustard and beet (*dha muoi*), eggplant (*ca muoi*)	Acidic, wet	*Lb. fermentum, Lb. pentosus, Lb. plantarum, Ped. pentosaceus, Lb. brevis, Lb. paracasei, Lb. pantheris, Ped. acidilactici*	Vietnam	Nguyen et al. (2013b)
Dakguadong	Mustard leaf	Salad	*Lb. plantarum*	Thailand	Rhee et al. (2011)
Ekung	Bamboo shoot	Acidic, sour, soft, curry	*Lb. plantarum, Lb. brevis, Lb. casei, Tor. halophilus*	India	Tamang and Tamang (2009)
Eup	Bamboo shoot	Acidic, sour, dry, curry	*Lb. plantarum, Lb. fermentum, Lb. brevis, Lb. curvatus, Ped. pentosaceus, Leuc. mesenteroides, Leuc. fallax, Leuc. lactis, Leuc. citreum, Ent. durans*	India	Tamang and Tamang (2009)
Fu-tsai	Mustard	Acidic, sour	*Ent. faecalis, Lb. alimentarius, Lb. brevis, Lb. coryniformis, Lb. farciminis, Lb. plantarum, Lb. versmoldensis, Leuc. citreum, Leuc. mesenteroides, Leuc. pseudomesenteroides, Ped. pentosaceus, W. cibaria, W. paramesenteroides*	Taiwan	Chao et al. (2009, 2012)

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Goyang	Wild vegetable	Acidic, sour, wet, soup	*Lb. plantarum, L. brevis, Lact. lactis, Ent. faecium, Ped. pentosaceus, Candida* sp.	India, Nepal	Tamang and Tamang (2007)
Gundruk	Leafy vegetable	Acidic, sour, dry, soup, side-dish	*Lb. fermentum, Lb. plantarum, Lb. casei, Lb. casei* subsp. *pseudoplantarum, Ped. pentosaceus ,*	India, Nepal, Bhutan	Karki et al. (1983), Tamang et al. (2005)
Hirring	Bamboo shoot tips	Acidic, sour, wet, pickle	*Lb. brevis, Lb. plantarum, Lb. curvatus, Ped. pentosaceus, Leuc. mesenteroides, Leuc. fallax, Leuc. lactis, Leuc. citreum, Ent. durans, Lact. lactis*	India	Tamang and Tamang (2009)
Hom-dong	Red onion	Fermented red onion	*Leuc. mesenteroides, Ped. cerevisiae, Lb. plantarum, Lb. fermentum, Lb. buchneri*	Thailand	Phithakpol et al. (1995)
Hum-choy	Gai-choy	Chinese sauerkraut	*Pediococcus* sp., *Streptococcus* sp.,	China	Phithakpol et al. (1995)
Inziang-sang	Mustard leaves	Acidic, sour, dry, soup	*Lb. plantarum, Lb. brevis, Ped. acidilactici*	India	Tamang et al. (2005)
Jeruk	Fruits and vegetables	Acidic, wet	LAB	Malaysia	Merican (1996)
Jiang-sun	Bamboo shoot, salt, sugar, *douchi* (fermented soybeans)	Fermented bamboo, side dish	*Lb. plantarum, Ent. faecium, Lc. lactis* subsp. *lactis*	Taiwan	Chen et al. (2010)
Khalpi	Cucumber	Acidic, sour, wet, pickle	*Lb. brevis, Lb. plantarum, Ped. pentosaceus, Ped. Acidilactici, Leuc. Fallax*	India, Nepal	Tamang et al. (2005), Tamang and Tamang (2010)

(*Continued*)

Table 1.3 (*Continued*) Some Common and Uncommon Ethnic Fermented Vegetable Products of the World

Product	*Substrate/Raw Materials*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Kimchi (beachoo)	Cabbage, green onion, hot pepper, ginger	Acidic, mild-sour, wet, side-dish	*Leuc. mesenteroides, Leuc. citreum, Leuc. gasicomitatum, Leuc. kimchii, Leuc. inhae, W. koreensis, W. cibaria, Lb. plantarum, Lb. sakei, Lb. delbrueckii, Lb. buchneri, Lb. brevis, Lb. fermentum, Ped. acidilactici, Ped. pentosaceus*	Korea	Nam et al. (2009), Jung (2012)
Kimchi (Dongchimi)	Radish, salt, water	Acidic, mild-sour, wet, soup, side-dish	*Leuc. mesenteroides, Lb. plantarum, Lb. brevis, Ped. cerevisiae*	Korea	Nam et al. (2009), Jung (2012)
Kimchi (Kakdugi)	Radish, salt, garlic, green onion, hot pepper, ginger	Acidic, mild-sour, wet, side-dish	*Leuc. mesenteroides, , Lb. plantarum, Lb. brevis, Ped. cerevisiae*	Korea	Nam et al. (2009), Jung (2012)
Lung-siej	Bamboo shoot	Sour-acidic, soft	*Lb. brevis, Lb. plantarum, Lb. curvatus, Ped. pentosaceus, Leuc. mesenteroides, Leuc. fallax, Leuc. lactis, Leuc. citreum, Ent. durans*	India	Tamang (2010a)
Naw-mai-dong	Bamboo shoots	Acidic, wet	*Leuc. mesenteroides, Ped. cerevisiae, Lb. plantarum, Lb. brevis, Lb. fermentum, Lb. buchneri*	Thailand	Phithakpol et al. (1995)
Mesu	Bamboo shoot	Acidic, sour, wet	*Lb. plantarum, Lb. brevis, Lb. curvatus, Leu, citreum, Ped. pentosaceus*	India, Nepal, Bhutan	Tamang and Sarkar (1996), Tamang et al. (2008)
Oiji	Cucumber, salt, water	Fermented cucumber	*Leuc. mesenteroides, Lb. brevis, Lb. plantarum, Ped. cerevisiae*	Korea	Alexandraki et al. (2013)

Olives (fermented)	Olive	Acidic, wet, Salad, side dish	*Leuc. mesenteroides, Ped. pentosaceus; Lb. plantarum Lb. pentosus/Lb. plantarum, Lb. paracollinoides, Lb. vaccinostercus/ Lb. suebicus* and *Pediococcus* sp. non-lactics (*Gordonia* sp./*Pseudomonas* sp., *Halorubrum orientalis, Halosarcina pallid, Sphingomonas* sp./ *Sphingobium* sp./*Sphingopyxis* sp., *Thalassomonas agarivorans*) and yeasts (*Candida* cf. *apicola, Pichia* sp., *Pic. manshurica/Pic. galeiformis, Sacch. cerevisiae*)	USA, Spain, Portugal, Peru, Chile	Abriouel et al. (2011)
Pak-gard-dong	Leafy vegetable, salt, boiled rice	Acidic, wet, side dish	*Lb. plantarum, Lb. brevis, Ped. cerevisiae*	Thailand	Phithakpol et al. (1995)
Pak-sian-dong	Leaves of *Gynandropis pentaphylla*	Acidic, wet, side dish	*Leuc. mesenteroides, Ped. cerevisiae, Lb. plantarum, Lb. germentum, Lb. buchneri*	Thailand	Phithakpol et al. (1995)
Poi	Taro corms	Acidic, semi-solid	LAB, yeasts	Hawaii	Alexandraki et al. (2013)
Pao cai	Cabbage	Sweet and sour rather than spicy, breakfast	*Lb. pentosus, Lb. plantarum, Lb. brevis, Lb. lactis, Lb. fermentum, and Leuc. mesenteroides,* and *Ped. pentosaceus*	China	Yan et al. (2008)
Sauerkraut	Cabbage	Acidic, sour, wet, salad, side dish	*Leuc. mesenteroides, Ped. pentosaceus; Lb. brevis, Lb. plantarum, Lb. sakei*	Europe, USA, Canada, Australia	Johanningsmeier et al. (2007)

(*Continued*)

Table 1.3 (*Continued*) Some Common and Uncommon Ethnic Fermented Vegetable Products of the World

Product	*Substrate/Raw Materials*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Sayur asin	Mustard leaves, cabbage, salt, coconut	Acidic, sour, wet, salad	*Leuc. mesenteroides, Lb. plantarum, Lb. brevis, Lb. confuses, Ped. pentosaceus*	Indonesia	Puspito and Fleet (1985)
Sinnamani	Radish	Acidic, sour, wet	LAB	Nepal	Tamang (2010a)
Soibum	Bamboo shoot	Acidic, sour, soft, curry	*Lb. plantarum, Lb. brevis, Lb. coryniformis, Lb. delbrueckii, Leuc. fallax, Leuc. Lact. lactis, Leuc. mesenteroides, Ent. durans, Strep. lactis, B. subtilis, B. lichniformis, B. coagulans, B. cereus, B. pumilus Pseudomonas fluorescens, Saccharomyces* sp., *Torulopsis* sp.	India	Jeyaram et al. (2009), Tamang et al. (2012)
Soidon	Bamboo shoot tips	Acidic, sour, soft, curry	*Lb. brevis, Leuc. fallax, Lact. lactis*	India	Tamang et al. (2008)
Soijim	Bamboo shoot	Acidic,liquid, condiment	*Lb. brevis, Lb. plantarum, Lb. curvatus, Ped. pentosaceus, Leuc. mesenteroides, Leuc. fallax, Leuc. lactis, Leuc. citreum, Ent. durans*	India	Tamang et al. (2008)
Sinki	Radish tap-root	Acidic, sour, dry, soup, pickle	*Lb. plantarum, Lb. brevis, Lb. casei, Leuc. fallax*	India, Nepal, Bhutan	Tamang and Sarkar (1993), Tamang et al. (2005)
Suan-cai	Vegetables	Acidic, sour, wet	*Ped. pentosaceus, Tetragenococcus halophilus*	China	Chen et al. (2006)

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Suan-tsai	Mustard	Acidic, sour, dry	*Ent. faecalis, Lb. alimentarius, Lb. brevis, Lb. coryniformis, Lb. farciminis, Lb. plantarum, Lb. versmoldensis, Leuc. citreum, Leuc. mesenteroides, Leuc. pseudomesenteroides, Ped. pentosaceus, W. cibaria, W. paramesenteroides*	Taiwan	Chao et al. (2009)
Sunki	Turnip	Acidic, sour, wet	*Lb. plantarum, Lb. fermentum, Lb. delbrueckii, Lb. parabuchneri, Lb. kisonensis, Lb. otakiensis, Lb. rapi, Lb. sunkii*	Japan	Endo et al. (2008), Watanabe et al. (2009a)
Takuanzuke	Japanese radish, salt, sugar, *Shochu*	Pickle radish	*Lb. plantarum, Lb. brevis, Leuc. mesenteroides, Streptococcus* sp., *Pediococcus* sp., yeasts	Japan	Alexandraki et al. (2013)
Takanazuke	Broad leaved mustard, red pepper, salt, turmeric	Vegetable pickle Takuanzuke	*Ped. halophilus, Lb. plantarum, Lb. brevis*	Japan	Alexandraki et al. (2013)
Tuaithur	Bamboo shoot	Solid, wet, sour, curry	*Lb. plantarum, Lb. brevis, Ped. pentosaceou, Lc. lactis, Bacillus circulans, B. firmus, B. sphaericus, B. subtilis*	India	Chakrabarty et al. (2014)
Tuairoi	Bamboo shoot	Solid, dry, sour, curry	*Lb. plantarum, Ent. faecium, Ped. pentosaceous, Leuc. mesenteroides, B. laterosporus, B. circulans, B. stearothermophilus, B. firmus, B. cereus*	India	Chakrabarty et al. (2014)
Yan-Jiang	Ginger	Pickle	LAB	Taiwan	Chang et al. (2011)

from the fermented bamboo shoots of India (Jeyaram et al. 2010). *Jiang-sun* is a traditional fermented bamboo shoot food in Taiwan (Chen et al. 2010).

1.5.4 Fermented Legumes

Among the fermented legumes (Table 1.4), most of the products are of soybean origin. Two types of fermented soybean foods are produced: soybeans which are naturally fermented by *Bacillus* spp. (mostly *B. subtilis*) with characteristic stickiness, and soybeans which are fermented by filamentous molds (mostly *Aspergillus, Mucor, Rhizopus*). The *Bacillus*-fermented sticky soybean foods of Asia are *natto* of Japan (Kubo et al. 2011), *chungkokjang* of Korea (Shin et al. 2012), *kinema* of India, Nepal, and Bhutan (Tamang 2001), *aakhune, bekang, hawaijar, peruyaan*, and *tungrymbai* of India (Tamang et al. 2009), *thua nao* of Thailand (Dajanta et al. 2011), *pepok* of Myanmar (Tamang 2010b) and *sieng* of Cambodia and Laos (Tamang 2010b). Mold-fermented soybean products are *miso* and *shoyu* of Japan (Sugawara 2010), *tempeh* of Indonesia (Nout and Kiers 2005), *douchi* of China (Zhang et al. 2007), *sufu* of China (Han et al. 2001), *doenjang* of Korea (Kim et al. 2009). Among the common non-soybean fermented legumes of the world are *bikalga, dawadawa, iru, soumbala, ugba* of Africa (Parkouda et al. 2009, Ouoba et al. 2010), *dhokla, papad*, and *wari* of India (Nagai and Tamang 2010), *ontjom* of Indonesia (Nagai and Tamang 2010), and *maseura* of India and Nepal (Chettri and Tamang 2008).

The species of *Bacillus* isolated from *kinema* include *B. cereus, B. circulans, B. licheniformis, B. sphaericus, B. subtilis*, and *B. thuringiensis* (Sarkar et al. 1994, 2002, Tamang 2003), however, *B. subtilis* is the dominant functional bacterium in *kinema* (Sarkar and Tamang 1994, Tamang and Nikkuni 1996). *Ent. faecium* is also present in *kinema* (Sarkar et al. 1994). Based on molecular identification tools using ARDRA, ITS-PCR, and RAPD-PCR techniques, the species of *Bacillus* were isolated from *tungrymbai* (or *turangbai)* and *bekang,* naturally fermented soybean foods of the states of Meghalaya and Mizoram in North East India and were identified as *B. subtilis, B. pumilus, B. licheniformis, B. cereus, B. coagulans, B. circulans, B. brevis*, and *Lysinibacillus fusiformis* (Chettri 2013). *B. subtilis, B. licheniformis, B. cereus, Staphylococcus aureus, Staph. sciuri, Alkaligenes* spp., *Providencia rettgeri* were isolated from *hawaijar* of the state of Manipur in India (Jeyaram et al. 2008a).

Species of *Bacillus* isolated from naturally fermented *chungkokjang* are *B. amyloliquefaciens B. licheniformis*, and *B. subtilis* (Tamang et al. 2002, Choi et al. 2007, Kwon et al. 2009), *B. subtilis* subsp. *chungkokjang* (Park et al. 2005), *B. megaterium* (Shon et al. 2007). *Ent. faecium* is also present in *chungkukjang* (Yoon et al. 2008). Nam et al. (2012) analyzed 12,697 bacterial pyrosequences in *chungkukjang* and found that almost all the bacteria were members of the phylum *Firmicutes* (>95%), with only a small portion belonging to *Proteobacteria* (<5%). In various samples, specific unclassified *Bacillus* species and LAB existed as the dominant microbes of *chungkukjang* (Nam et al. 2012).

Japanese *natto* is the only *Bacillus*-fermented soybean food which is now produced by commercial mono-culture starter *B. natto*, first isolated from naturally fermented *natto* by Sawamura (1906). *B. natto* differs from *B. subtilis* on account of biotin requirement, production of polyglutamate, possession of 5.7-kb and 60-kb plasmids (Hara et al. 1983, Nagai et al. 1997), and insertion sequences (Nagai et al. 2000, Kimura and Itoh 2007). *Thua nao*, an ethnic fermented nonsalty sun-dried wafer-type soybean food of Thailand, is used as a seasoning. *B. subtilis* is a functional bacterium in *thua nao* (Chunhachart et al. 2006, Inatsu et al. 2006).

Rhizopus microsporus is a functional mold for fermentation of *tempeh* with varieties *Rhi. microsporus, Rhi. oligosporus, Rhi. rhizopodiformis, Rhi. tuberosus*, and *Rhi. chinensis*

Table 1.4 Some Common and Uncommon Ethnic Fermented Legume (Soybeans and Non-Soybean) Products of the World

Product	*Substrate/Raw Material*	*Sensory Features and Nature*	*Microorganisms*	*Country*	*References*
Aakhone	Soybean	Alkaline, sticky, paste	*B. subtilis, Proteus mirabilis*	India	Singh et al. (2014)
Bekang	Soybean	Alkaline, sticky, Paste, curry	*B. subtilis, B. pumilus, B. licheniformis, B. sphaericus, B. brevis, B. coagulans, B. circulans, B. amyloliquefaciens, Ent. faecium, Ent. durans, Ent. hirae, Ent. Raffinossus, Ent. cecorum, Proteus mirabilis Sacch. cerevisiae, Debaryomyces hansenii, Pic. burtonii.*	India	Chettri (2013), Singh et al. (2014)
Bhallae	Black gram	Mild acidic, side dish	*B. subtilis, Candida curvata, C. famata, C. membraneafaciens, C. variovaarai, Cryptococcus humicoius, Deb. hansenii, Geotrichum candidum, Hansenula anomala, H. polymorpha, Kl. marxianus, Lb. fermentum, Leuc. mesenteroides, Ped. membranaefaciens, Rhiz. marina, Sacch. cerevisiae, Ent. faecalis, Trichosporon beigelii, Trichosporon pullulans, Wingea robertsii*	India	Rani and Soni (2007)
Bikalga	Roselle (*Hibiscus sabdariffa*)	Condiment	*B. subtilis, B. licheniformis, B. megaterium, B. pumilus*	Burkina Faso	Ouoba et al. (2007a,b)
Ce-lew	Soybean, corn flour, rice flour, salt	Soya sauce	*Ped. halopholus, Bacillus* sp., *Asp. oryzae, Asp. flavus*	Thailand	Alexandraki et al. (2013)
Chee-fan	Soybean whey curd	Cheese-like, solid	*Mucor* sp., *Asp. glaucus*	China	Blandino et al. (2003)

(*Continued*)

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Table 1.4 (*Continued*) Some Common and Uncommon Ethnic Fermented Legume (Soybeans and Non-Soybean) Products of the World

Product	*Substrate/Raw Material*	*Sensory Features and Nature*	*Microorganisms*	*Country*	*References*
Chungkokjang (or *jeonkukjang, cheonggukjang*	Soybean	Alkaline, sticky, soup	*B. subtilis, B. amyloliquefaciens, B. licheniformis, B. cereus, Pantoea agglomerans, Pantoega ananatis, Enterococcus* sp., *Pseudomonas* sp., *Rhodococcus* sp.	Korea	Hong et al. (2012), Shin et al. (2012)
Dage	Coconut press cake, *Ragi*	Solid, side dish	*Rhizopus* sp.,	Indonesia	Alexandraki et al. (2013)
Douchi	Soybean	Alkaline, paste	*B. amyloliquefaciens, B. subtilis, Asp. oryzae*	China, Taiwan	Wang et al. (2006), Zhang et al. (2007)
Dawadawa	Locust bean	Alkaline, sticky	*B. pumilus, B. licheniformis, B. subtilis, B. firmus, B. atrophaeus, B. amyloliquefaciens, B. mojavensis, Lysininbacillus sphaericus.*	Ghana, Nigeria	Amoa-Awua et al. (2006), Meerak et al. (2008)
Dhokla	Bengal gram	Mild acidic, spongy, Steamed, snack	*Leuc. mesenteroides, Lb. fermenti, Ent. faecalis, Tor. candida, Tor. pullulans*	India	Blandino et al. (2003)
Doenjang	Soybean	Alkaline, paste	*B. subtilis, B. licheniformis, B. pumilis, Mu. plumbeus, Asp. oryzae, Deb. hansenii, Leuc. mesenteroides, Tor. halophilus, Ent. faecium, Lactobacillus* sp.	Korea	Kim et al. (2009), Shin et al. (2012)
Dosa	Rice, blackgram dhal (*Phaselus mango*)	Fermented fan cake	*Leuc. mesenteroides, Lb. delbrueckii, Lb. fermenti, Ent. faecalis, B. amyloliquefaciens, Cand. boidini, Cand. glabrata, Cand. sake, Deb. hansenii, Hansenula polymorpha, Issatchenkia terricola, Rhiz. graminis*	India, Sri Lanka	Soni et al. (1986)

Furu	Soybean curd	Mild acidic	*B. pumilus, B. megaterium, B. stearothermophilus, B. firmus, Staph. hominis*	China	Sumino et al. (2003)
Gochujang	Soybean, red pepper	Hot-flavored seasoning	*B. velegensis, B. amyloliquefacious, B. subtilis, B. liqueformis,* spcecis of *Oceanobacillus, Zygosaccharomyses, Candida lactis, Zygorouxii, Aspergillus, Penicillium, Rhizopus*	Korea	Nam et al. (2012), Kim et al. (2013).
Hawaijar	Soybean	Alkaline, sticky	*B. subtilis, B. licheniformis, B. amyloliquefaciens, B. cereus, Staph. aureus, Staph. sciuri, Alkaligenes* sp., *Providencia rettgers, Proteus mirabilis*	India	Jeyaram et al. (2008a), Singh et al. (2014)
Hishiho-Miso	Soybean, barley or wheat, salt, vegetables, Mizuame, sugar, shoyu	Sweetend Miso	*Asp. oryzae, Ped. halophilus, Sacch. Rouxii, Streptococcus* sp.	Japan	Sugawara (2010)
Iru	Locust bean	Alkaline, sticky	*B. subtilis, B. pumilus, B. licheniformis, B. megaterium, B. fumus, B. atrophaeus, B. amyloliquefaciens, B. mojavensis, Lysininbacillus sphaericus, Staph. saprophyticus*	Nigeria, Benin	Odunfa and Oyewole (1997), Meerak et al. (2008)
Kanjang	Soybean, meju, salt, water	Soya sauce	*Asp. oryzae, B. subtilis, B. pumillus, B. citreus, Sarcina mazima, Sacch. Rouxii*	Korea	Shin et al. (2012)
Kawal	Leaves of legume (*Cassia* sp.)	Alkaline, strong flavored, dried balls	*B. subilis, propionibacterium* sp., *Lb. plantarum, Staph. sciuri,* Yeasts	Sudan	Dirar et al. (2006)
Kecap	Soybean, wheat	Liquid	*Rhiz. oligosporus, Rhiz. oryzae, Asp. oryzae, Ped. halophilus, Staphylococcus* sp., *Candida* sp., *Debaromyces* sp., *Sterigmatomyces* sp.	Indonesia	Alexandraki et al. (2013)

(*Continued*)

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Table 1.4 (*Continued*) Some Common and Uncommon Ethnic Fermented Legume (Soybeans and Non-Soybean) Products of the World

Product	*Substrate/Raw Material*	*Sensory Features and Nature*	*Microorganisms*	*Country*	*References*
Ketjap	Soybean (black)	Syrup	*Asp. oryzae, Asp. flavus, Rhiz. oligosporus, Rhiz. arrhizus*	Indonesia	Alexandraki et al. (2013)
Kinda	Locust bean	Alkaline, sticky	*B. pumilus, B. licheniformis, B. subtilis, B. atrophaeus, B. amyloliquefaciens, B. mojavensis, Lysininbacillus sphaericus.*	Sierra Leone	Meerak et al. (2008)
Kinema	Soybean	Alkaline, sticky	*B. subtilis, B. licheniformis, B. cereus, B. circulans, B. thuringiensis, B. sphaericus, Ent. faecium, Cand. parapsilosis, Geotrichum candidum*	India, Nepal, Bhutan	Sarkar et al. (1994), Tamang (2003)
Khaman	Bengal gram	Mild acidic, spongy	*Leuc. mesenteroides, Lb. fermentum, Lact. lactis, Ped. acidilactici, Bacillus* sp.	India	Ramakrishnan (1979)
Koikuchi Shoyu	Defatted soybean flake, wheat, brine, tane-koji	Soy sauce	*Aspergillus sojae, Asp. oryzae, Sacch. rouxii, Tor. versatilis, Tor. echellsii, Ped. halophilus, Sacch. halomembransis, Ent. faecalis, Bacillus* sp.	Japan	Sugawara (2010)
Maseura	Black gram	Dry, ball-like, brittle, condiment	*B. subtilis, B. mycoides, B. pumilus, B. laterosporus, Ped. acidilactici, Ped. pentosaceous, Ent. durans, Lb. fermentum, Lb. salivarius, Sacch. cerevisiae, Pic. burtonii, Cand. castellii*	Nepal, India	Chettri and Tamang (2008)
Meitauza	Soybean	Liquid	*B. subtilis, Asp. oryzae, Rhiz. oligosporus, Mu. meitauza, Actinomucor elegans*	China, Taiwan	Zhu et al. (2008)

Meju	Soybean	Alkaline, paste	*Asp. flavus, Asp. fumigatus, Asp. niger, Asp. oryzae, Asp. retricus, Asp. spinosa, Asp. terreus, Asp. Wentii, Botrytis cineara Mu. adundans, Mu. circinelloides, Mu. griseocyanus, Mu. hiemalis, Mu. jasseni, Mu. Racemosus, Pen. citrinum, Pen. griseopurpureum, Pen. griesotula, Pen. kaupscinskii, Pen. lanosum, Pen. thomii, Pen. turalense, Rhi. chinensis, Rhi. nigricans, Rhi. oryzae, Rhi. Sotronifer; Candida edax, Can. incommenis, Can. utilis Hansenula anomala, Han. capsulata, Han. Holstii, Rhodotorula flava, Rho. glutinis, Sacch. exiguus, Sacch. cerevisiae, Sacch. kluyveri , Zygosaccharomyces japonicus, Zyg. rouxii; Bacillus citreus, B. circulans, B. licheniformis, B. megaterium, B. mesentricus, B. subtilis, B. pumilis, Lactobacillus* sp., *Ped. acidilactici*	Korea	Choi et al. (1995)
Miso	Soybean	Alkaline, paste	*Ped. acidilactici, Leuc. paramesenteroides, Micrococcus halobius, Zygosaccharomyces rouxii, Asp. oryzae*	Japan	Asahara et al. (2006)
Miso (Hishiho)	Soybean, barley or wheat, salt, vegetables, Mizuame (dextrose syrup), sugar, *shoyu*	Sweet miso	*Asp. oryzae, Ped. halophilus, Sacch. rouxii, Streptococcus* sp.	Japan	Sugawara (2010)

(*Continued*)

Health Benefits of Fermented Foods and Beverages

Table 1.4 (*Continued*) Some Common and Uncommon Ethnic Fermented Legume (Soybeans and Non-Soybean) Products of the World

Product	*Substrate/Raw Material*	*Sensory Features and Nature*	*Microorganisms*	*Country*	*References*
Miso (Kome Ama)	Rice, soybean, salt, *tane-koji*	Sweet rice miso	*Asp. oryzae, Streptococcus* sp., *Pediococcus* sp., *Sacch. rouxii*	Japan	Sugawara (2010)
Miso (Kome Kara)	Rice, soybean, salt, *tane-koji*, salt	Salt rice miso	*Asp. oryzae, Sacch. rouxii, Ped. halophilus, Tor. versalis, Tor. echellsii, Bacillus* sp.	Japan	Sugawara (2010)
Miso (Mame)	Cereal, soybean, salt		*Asp. oryzae, Asp. sojae, Ent. faecalis, Tor. versatilis, Bacillus* sp.	Japan	Sugawara (2010)
Miso (Mugi)	Barley, soybean, salt, *koji*	Barley Miso	*Asp. oryzae, Sacch. rouxii, Ped. halophilus, Ent. faecalis, Tor. versatilis, Tor. echellsii, Bacillus* sp.	Japan	Sugawara (2010)
Moromi	Soybean		*Aspergillus* sp., *Sacch. rouxii*	Japan	FAO (1998, 1999)
Natto	Soybean	Alkaline, sticky	*B. subtilis (natto)*	Japan	Nagai and Tamang (2010)
Oncom Hitam (Black *Oncom*) And *Oncom Merah* (Orange *Oncom*	Peanut press cake, tapioca, soybean curd starter	Fermented peanut press cake, roasted or fried	*Neurospora intermedia, N. crassa, N. sitophila* (from red *oncom*), *Rhi. oligosporus* (from black *oncom)*	Indonesia	Ho (1986)
Ogiri/Ogili	Melon seeds, castor oil seeds, pumpkin bean, sesame		*B. subtilis, B. pumilus, B. licheniformis, B. megaterium, B. rimus, Pediococcus* sp., *Staph. saprophyticus, Lb. plantarum*	West, East and Central Africa	Odunfa and Oyewole (1997)

Okpehe	Seeds from *Prosopis africana*	Alkaline, sticky	*B. subtilis, B. amyloliquefaciens, B. cereus, B. licheniformis*	Nigeria	Oguntoyinbo et al. (2010)
Owoh	Cotton seed		*B. subtilis, B. pumilus, B. licheniformis, Staph. saprophyticus*	West Africa	Odunfa and Oyewole (1997)
Papad	Black gram	Circular wafers	*Cand. krusei, Deb. hansenii, Lb. fermentum, Leuc. mesenteroides, P. membranaefaciens, Sacch. cerevisiae, Ent. faecalis, Trichosporon beigelii*	India, Nepal	Rani and Soni (2007)
Pepok	Soybean	Alkaline, sticky	*Bacillus* sp.	Myanmar	Nagai and Tamang (2010)
Peruyaan	Soybean	Alkaline, sticky	*B. subtilis, B. amyloliquefaciens, Vagococcus lutrae, Ped. acidilactici, Ent. faecalis*	India	Singh et al. (2014)
Sieng	Soybean	Alkaline, sticky	*Bacillus* sp.	Cambodia, Laos	Nagai and Tamang (2010)
Soumbala	Locust bean	Alkaline, sticky	*B. pumilus, B. atrophaeus, B. amyloliquefaciens, B. mojavensis, Lysininbacillus sphaericus. B. subtilis, B. thuringiensis, B. licheniformis, B. cereus, B. badius, B. firmus, B. megaterium, B. mycoides, B. sphaericus, Peanibacillus alvei, Peanibacillus larvae, Brevibacillus laterosporus*	Burkina Faso	Ouoba et al. (2003a,b, 2004)
Soy sauce	Soybean	Alkaline, liquid	*Asp. oryzae, Asp. niger, Sacch. rouxii, Ped. acidilactis, Ped. cerevisae, Ped. halophilus, Lb. delbrueckii*	Worldwide	Sugawara (2010)
Shoyu	Soybean	Alkaline, liquid, Seasoning	*Asp. oryzae* or *Asp. sojae, Z. Rouxii, C. versatilis*	Japan, Korea, China	Sugawara (2010)

(*Continued*)

Table 1.4 (*Continued*) Some Common and Uncommon Ethnic Fermented Legume (Soybeans and Non-Soybean) Products of the World

Product	*Substrate/Raw Material*	*Sensory Features and Nature*	*Microorganisms*	*Country*	*References*
Sufu	Soybean curd	Mild-acidic, soft	*Actinomucor elenans, Mu. silvatixus, Mu. corticolus, Mu. hiemalis, Mu. praini, Mu. racemosus, Mu. subtilissimus, Rhiz. chinensis*	China, Taiwan	Han et al. (2001)
Tamari Shoyu	Defatted soybean, salt, water, wheat	Soybean rich Shoyu	*Asp. sojae, Asp. oryzae, Sacch. rouxii, Tor. versaltilis, Tor. echellsii, Ped. halophilus, Ent. faecalis, Bacillus* sp.	Japan	Alexandraki et al. (2013)
Tauco	Soybean	Alkaline, paste, use as flavoring agent	*Rhiz. oryzae, Rhiz. ologosporus, Asp. oryzae, Lb. delbrueckii, Zygosaccharomyces soyae*	Indonesia	Winarno et al. (1973)
Tao-si	Soybean, salt, rice bran, wheat flour	Fermented soybean curd	*Asp. oryzae*	Philippines	Blandino et al. (2003)
Tempe	Soybean	Alkaline, solid, fried cake, breakfast	*Asp. niger, Rhiz. oligosporus, Rhiz. arrhizus, Rhiz. oryzae, Rhiz. stolonifer, Citrobacter freundii, Enterobacter cloacae, K. pneumoniae, K. pneumoniae* subsp. *ozaenae, Pseudomas fluorescens* as vitamin B_{12}-producing bacteria, *Lb. fermentum, Lb. lactis, Lb. plantarum, Lb. reuteri*	Indonesia (Origin), the Netherlands, Japan, USA	Nout and Kiers (2005), Jennessen et al. (2008)
Tempe Benguk	Velvet bean seeds, *Ragi* Tempe	Alkaline, solid, fried cake, breakfast	*Rhizopus* sp., *Rhiz. oligosporus, Rhiz. arrhizus*	Indonesia	Nagai and Tamang (2010)

Tempe Gembus	Solid residue of soybean curd, tapioca, *Ragi* tempe	Alkaline, solid, fried cake, breakfast	*Rhizopus* sp. *Rhiz. oryzae, Rhiz. oligosporus*	Indonesia	Alexandraki et al. (2013)
Tempe Kecipir	Winged bean seed, *Ragi*, old Tempe	Alkaline, solid, fried cake, breakfast	*Rhiz. oryzae, Rhiz. arrhizus, Rhiz. oligosporus, Rhiz. achlamydosporus*	Indonesia	Alexandraki et al. (2013)
Tempe Kedelai	Soybean, tapioca flour, maize, young papaya, cassava, coconut press cake, starter	Alkaline, solid, fried cake, breakfast	*Rhizopus* sp., *Rhiz. oryzae, Rhiz. oligosporus*	Indonesia	Alexandraki et al. (2013)
Tempe Koro Pedang	Jack bean seed (*Canavalia ensiformis*), *ragi*, old *tempe*	Alkaline, solid, fried cake, breakfast	*Rhiz. oryzae, Rhiz. arrhizus, Rhiz. achlamydosporus*	Indonesia	Alexandraki et al. (2013)
Tempe Lamtoro	Wied Tamarind (*Leucaena Leucocephala*)	Alkaline, solid, fried cake, breakfast	*Rhizopus* sp., *Rhiz. oryzae*	Indonesia	Alexandraki et al. (2013)
Thua nao	Soybean	Alkaline, paste, dry, side dish	*B. subtilis, B. pumilus, Lactobacillus* sp.	Thailand	Chunhachart et al. (2006)

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Table 1.4 (*Continued*) Some Common and Uncommon Ethnic Fermented Legume (Soybeans and Non-Soybean) Products of the World

Product	*Substrate/Raw Material*	*Sensory Features and Nature*	*Microorganisms*	*Country*	*References*
Tofu (stinky tofu)	Soybean	Alkaline, liquid	*Bacillus* sp., *Ent. hermanniensis, Lb. agilis, Lb. brevis, Lb. buchneri, Lb. crispatus, Lb. curvatus, Lb. delbrueckii, Lb. farciminis, Lb. fermentum, Lb. pantheris, Lb. salivarius, Lb. vaccinostercus, Lc. lactis, Lactococcus* sp., *Leuc. camosum, Leuc. citreum, Leuc. fallax, Leuc. lactis, Leuc. mesenteroides, Leuc. pseudomesenteroides, Ped. acidilactici, Strep. bovis, Strep. macedonicus, W. cibaria, W. confusa, W. paramesenteroides, W. soli*	China, Japan	Chao et al. (2008)
Toyo	Soybean, salt, brown sugar, wheat starter	Cowpea sauce	*Asp. oryzae, Hansenula anomala, Hansenula subpelliculosa, Lb. delbrueckii*	Philippines	Alexandraki et al. (2013)
Tungrymbai/ turangbai	Soybean	Alkaline, sticky, curry, soup	*B. subtilis, B. pumilus, B. licheniformis, B. amyloliquefaciens, Lb. brevis, Ent. faecium, Ent. durans, Ent. hirae, Ent. Raffinossus, Ent. cecorum, Vagococcus carniphilus Sacch. cerevisiae, Debaryomyces hansenii, Pic. burtonii,*	India	Chettri (2013), Singh et al. (2014)

Tuong	Rice, maize, salt	Staple	*Asp. oryzae, Sacch. rouxii, Ped. halophilus*	Vietnam	Alexandraki et al. (2013)
Ugba	African oil bean (*Pentaclethra macrophylla*)	Alkaline, flat, glossy, brown in color	*B. subtilis, B. pumilus, B. licheniformis, Staph. saprophyticus*	Nigeria	Odunfa and Oyewole (1997)
Uri	Locust bean	Alkaline, sticky, condiment, soup	*Bacillus* spp.	West Africa	Alexandraki et al. (2013)
Usukuchi Shoyu	Soybean, wheat, Tane-Koji, Amasake	Soy sauce, seasoning	*Asp. oryzae, Sacch. rouxii,* tor. *versatilis, Tor. echellsii, Ped. halophilus, Sacch. halomembransis, Ent. faecalis, Bacillus* sp.	Japan	Alexandraki et al. (2013)
Vadai	Black gram	Paste, side dish	*Pediococcus* sp., *Streptococcus* sp., *Leuconostoc* sp.	India	Blandino et al. (2003)
Wari	Black gram	Ball-like, brittle, side dish	*B. subtilis, Cand. curvata, Cand. famata, Cand. krusei, Cand. parapsilosis, Cand. vartiovaarai, Cryptococcus humicolus, Deb. hansenii, Deb. tamarii, Geotrichum candidum, Hansenula anomala, Kl. marxianus, Sacch. cerevisiae, Rhiz. lactosa, Ent. faecalis, Wingea robetsii, Trichosporon beigelii*	India	Rani and Soni (2007)

(Nout and Kiers 2005, Jennessen et al. 2008). *Citrobacter freundii, Enterobacter cloacae, Kl. pneumoniae, Kl. pneumoniae* subsp. *ozaenae, Pseudomonas fluorescens* as vitamin B_{12}-producing bacteria, and LAB—*Lb. fermentum, Lb. lactis, Lb. plantarum, Lb. reuteri* are important microorganisms in naturally fermented *tempeh* (Denter and Bisping 1994, Feng et al. 2005). Four types of *douchi* are produced in China: *Mucor*-fermented *douchi, Aspergillus*-fermented *douchi, Rhizopus*-fermented *douchi,* and *Bacillus*-fermented *douchi* (Zhang et al. 2007). *Aspergillus awamori, Asp. kawachii, Asp. oryzae, Asp. Shirousamii*, and *Asp. sojae* have been widely used as the starter in preparation of *koji* in Japan for production of *miso* and *shoyu* (Kitamoto 2002, Matsushita et al. 2009). *B. subtilis, B. licheniformis, Ent. faecium, Leuc. mesenteroides, Tetra. halophilus*, and *Asp. oryzae, Debaryomyces hansenii*, and *Mucor plumbeus* were isolated from *doenjang* (Kim et al. 2009). Using next-generation sequencing, Nam et al. (2011) have analysed the microbial community of traditional Korean soybean pastes, and derived 17,675 bacterial sequences from nine local and two commercial brands of *doenjang* samples.

Bikalga, dawadawa, iru, mbodi, ntoba and *soumbala* are the ethnic nonsalted fermented locust bean (*Parkia biglobosa*) foods of Africa. Microorganisms involved are *B. amyloliquefaciens, B. lichenifornis, B. megaterium, B. pumilus, B. subtilis, Enterococcus avium, Ent. casseliflavus, Ent. faecalis, Ent. faecium, Ent. hirae, Lb. plantarum, Micrococcus* spp., *Ped. acidilactici, Ped. pentosaceus, Staphylococcus* (*Staph.*) *hominis, Staph. saprophyticus, Staph. xylosus,, Weissella cibaria*, and *W. confusa* (Amoa-Awua et al. 2006, Azokpota et al. 2006, Meerak et al. 2008, Ouoba et al. 2010). Although *B. subtilis* has been reported as the dominant bacterium involved in the fermentation, other *Bacillus* spp. such as *B. amyloliquefaciens, B. cereus*, and *B. licheniformis* have also been detected, for example, in *okpehe* produced in Nigeria from *Prosopis africana* (legume) seeds, thus suggesting the inter-species diversity in these kinds of products (Oguntoyinbo et al. 2010). A study by Ouoba et al. (2008) reflects the interspecies diversity characterizing this fermentation, comprising *B. subtilis* as the predominant organism followed by *B. licheniformis*, while strains of *B. cereus, B. pumilus, B. badius, Brevibacillus bortelensis, B. sphaericus*, and *B. fusiformis* were also detected. A number of studies have been undertaken to develop starter cultures for the fermentation of indigenous legumes, such as the seeds of *Prosopis africana* (Oguntoyinbo et al. 2007), and of the African locust bean (*Parkia biglobosa*) (Ouoba et al. 2003a,b, 2004, 2005, 2007a,b).

1.5.5 Fermented Root Crop and Tuber Products

Cassava (*Manihot esculenta*) root is traditionally fermented into staple foods such as *gari* of Nigeria, *fufu* of Togo, Burkina Faso, Benin, Nigeria and Ghana, *agbelima* of Ghana, *chikawgue* of Zaire, *kivunde* of Tanzania, and *kocho* of Ethiopia (Table 1.5). *Gari* making involves several stages including fermentation, dextrinization, partial gelatinization, and tetrogradation (Abimbola 2007). In initial stage of fermentation of cassava is dominated by *Corynebacterium manihot* (Oyewole et al. 2004). *Lb. acidophilus, Lb. casei, Lb. fermentum, Lb. pentosus, Lb. plantarum* are present in *gari* (Oguntoyinbo and Dodd 2010). *Lb. plantarum, Leuconostoc* sp., and *Streptococcus* spp. play a major role in detoxification of the cyanogenic glucosides during *gari* fermentation (Ngaba and Lee 1979). *Geotrichum candidum* is the dominant yeast responsible for the characteristic taste and aroma of *gari* (Okafor and Ejiofor 1990).

Cassava root is also traditionally fermented into a sweet dessert such as *tapé* in Indonesia (Ardhana and Fleet 1989). A mixed culture of *Streptococcus, Rhizopus*, and *Saccharomycopsis* produces the aroma in the *tapé*, whereas *Sm. fibuligera* produces α-amylase and *Rhizopus* sp. produces glucoamylase (Suprianto et al. 1989). *Simal tarul ko jaanr* is a mild-alcoholic food beverage prepared from cassava root in Nepal and India (Tamang et al. 1996).

Table 1.5 Some Ethnic Fermented Root Crop Products of the World

Product	*Substrate/ Raw Materials*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Chikwangue	Cassava	Solid state, staple	Species of *Corynebacterium, Bacillus, Lactobacillus, Micrococcus, Pseudomonas, Acinetobacter, Moraxella*	Central Africa, Zaire	Odunfa and Oyewole (1997)
Cingwada	Cassava	Solid state	Species of *Corynebacterium, Bacillus., Lactobacillus, Micrococcus*	East and Central Africa	Odunfa and Oyewole (1997)
Dage	Coconut press cake, *ragi*		*Rhizopus* sp.	Indonesia	Alexandraki et al. (2013)
Fufu	Cassava	Submerged, staple	*Bacillus* sp., *Lb. plantarum, Leuc. mesenteroides, Lb. cellobiosus, Lb. brevis; Lb. coprophilus, Lact. lactis; Leuc. lactis, Lb. bulgaricus, Klebsiella* sp., *Leuconostoc* sp., *Corynebacterium* sp., *Candida* sp.	West Africa	Odunfa and Oyewole (1997)
Iape Ketela	Cassava, *ragi*		Species of *Rhizopus, Chlamydomucor, Candida, Saccharomyces, Endomycopsis*	Indonesia	Alexandraki et al. (2013)
Gari	Cassava	Solid state, staple	*Corynebacterium mannihot, Geotrichum* sp., *Lb. plantarium, Lb. buchnerri, Leuconostoc* sp., *Streptococcus* sp.	West and Central Africa	Oyewole et al. (2004)
Lafun/ Konkonte	Cassava	Submerged, staple	*Bacillus* sp., *Klebsiella* sp., *Candida* sp., *Aspergillus* sp., *Leuc. mesenteroides, Corynebacterium manihot, Lb. plantarum, Micrococcus luteus, Geotrichum candidum*	West Africa	Odunfa and Oyewole (1997)

(*Continued*)

Table 1.5 (*Continued*) Some Ethnic Fermented Root Crop Products of the World

Product	*Substrate/ Raw Materials*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Peujeum	Cassava roots	Acidic, solid, eaten after baking	Yeasts, mold	Indonesia	Alexandraki et al. (2013)
Simal tarul to jaanr	Cassava	Sweet, mild-alcoholic food, staple	*Mu. circinelloides, Rhi. Chinensis,- Pichia anomala, Sacch. cerevisiae, Candida glabrata, Saccharomycopsis fibuligera, Ped. pentosaceus, Lb. bifermentans*	India and Nepal	Tamang (2005)
Tapé	Cassava	Sweet dessert	*Streptococcus* sp., *Rhizopus* sp., *Saccharomycopsis fibuligera*	Indonesia	Suprianto et al. (1989)
Tapai Ubi	Cassava, Ragi	Sweet dessert	*Saccharomycopsis fibuligera, Amylomyces rouxii, Mu. circinelloides, Mu. javanicus, Hansenula* spp., *Rhi. arrhizus, Rhi. oryzae, Rhi. chinensis*	Malaysia	Merican and Yeoh (1989)

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1.5.6 Fermented Fruit Products

Some fermented fruit pickles are *atchara* (green unripe papaya), *burong mangga* (green unripe mango), *burong prutas* (local fruits) of the Philippines, *achar* of India and Nepal, and so on (Table 1.6). *Ca muoi* is a fermented fruit of Vietnam, and *tempoyak* is a fermented durian fruit of Malaysia. *Sacch. cerevisiae, Schizosaccharomyces pombe, Lb. plantarum,* and *Leuc. mesenteroides* were isolated from *palm wine/emu,* a fermented palm fruit of West Africa (Odunfa and Oyewole 1997). *Lb. plantarum* strains were isolated from Thai fermented fruits (Tanganurat et al. 2009).

1.5.7 Fermented Meat Products

Traditionally preserved and fermented meat products (Table 1.7) of many countries are the *salami* of Europe (Toldra 2007), *alheira* of Portugal (Albano et al. 2009), *androlla* of Spain (Garcia-Fontan et al. 2007), *nham* of Thailand (Chokesajjawatee et al. 2009), *kargyong, satchu*, and *suka ko masu* of India and Nepal (Rai et al. 2009, 2010), *arjia, chartayshya* and *jamma* of India (Oki et al. 2011), and *nem chua* of Vietnam (Khanh et al. 2011, Nguyen et al. 2011). The major microorganisms involved in meat fermentation are a species of LAB and coagulase-negative cocii, however, yeasts and enterococci are also present in some meat products (Rantsiou and Cocolin 2006). Identification based on the culture-independent approach using the DGGE-method has revealed *Lb. curvatus* and *Lb. sakei* as the main species of LAB involved in the transformation process, accompanied by coagulase-negative cocci *Staphy. xylosus* during meat fermentation and ripening (Cocolin et al. 2011). *Lb. curvatus, Lb. paraplantarum, Lb. plantarum, Lb. sakei, Lb. brevis, Lb. carnis, Lb. casei, Lb. curvatus, Lb. divergens, Lb. sanfransiscensis, Leuc. carnosum, Leuc. gelidium, Leuc. pseudomesenteroides, Leuc. citreum, Leuc. mesenteroides, Ped. acidilactici, Ped. pentosaceus, W. cibaria, W. viridescens, B. lentus, B. licheniformis, B. mycoides, B. subtilis, B. thuringiensis, E. cecorum, E. durans, E. faecalis, E. faecium, E. hirae* are the dominant LAB in fermented meats (Albano et al. 2009, Rai et al. 2010, Cocolin et al. 2011, Oki et al. 2011, Nguyen et al. 2013a); and also coagulase-negative staphylococci, micrococci, Enterobacteriaceae in fermented meats (Marty et al. 2011). The species of yeasts present in Spanish fermented sausages are *C. intermedia/curvata, C. parapsilosis, C. zeylanoides, Citeromyces matritensis, Trichosporon ovoides*, and *Yarrowia lipolytica* (Encinas et al. 2000).

1.5.8 Fermented, Dried and Smoked Fish Products

Preservation of fish through fermentation, sun drying, smoking and salting is traditionally performed by people living in coastal regions, or near lakes and rivers, and such preserved/fermented fish products are consumed as seasoning, condiments, curry and on the side (Salampessy et al. 2010). Some ethnic fermented fish products of the world (Table 1.8) are *hentak, ngari,* and *tungtap* of India (Thapa et al. 2004), and *bordia, karati,* and *lashim* of India (Thapa et al. 2007), *jeotgal* or *jeot* or *saeu-jeot* of Korea (Guan et al. 2011, Jung et al. 2013), *plaa-som* of Thailand (Saithong et al. 2010), *shiokara* of Japan (Fujii et al. 1999), *patis* of the Philippines (Steinkraus 1996), *surströmming* of Sweden (Kobayashi et al. 2000a), and sun-dried or smoked fish products such as *gnuchi, sidra, sukuti* of India, Nepal, and Bhutan (Thapa et al. 2006), *Ent. faecalis, Lb. plantarum, Lb. reuteri, Strep. salivarius,* species of *Bacillus, Micrococcus, Pediococcus* and yeasts including species of *Candida* and *Saccharomyces* are reported from fermented fish products of Thailand (Saithong et al. 2010, Hwanhlem et al. 2011). *Micrococcus* and *Staphylococcus* are dominant bacterial genera during ripening of *shiokara* (Wu et al. 2000). *Haloanaerobium praevalens* has been

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Table 1.6 Some Ethnic Fermented Fruit Products of the World

Product	*Substrate/Raw Materials*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Achar/ chatney	Fruits, vegetables, oil, salt	Acidic, hot and sour, pickle	LAB	India, Nepal, Pakistan, Bangladesh	Tamang (2010b)
Atchara	Green unripe papaya, onion, red pepper, garlic, ginger, salt	Unripe papaya pickle	*Leuc. mesenteroides, Lb. brevis, Lb. plantarum, Strep. faecalis, Ped. cerevisiae*	Philippines	Alexandraki et al. (2013)
Burong Mangga	Green unripe mango, salt	Pickled green mango		Philippines	Alexandraki et al. (2013)
Burong Prutas	Fruits, salt, sugar	Picked fruits	*Lb. brevis, Lb. plantarum, Leuc. mesenteroides*	Philippines	Alexandraki et al. (2013)
Chuk	Fruits	Sour, dark-brown paste, therapeutic uses	unknown	Nepal, India	Tamang (2005)
Ogiri	Melon seeds	Alkaline, condiment	LAB, *Bacillus* spp.	Nigeria	Tamang (2010b)
Owoh	Cotton seeds	Alkaline, condiment	LAB, *Bacillus*	Nigeria	Tamang (2010b)
Tempoyak	Durian fruit	Fermented durian fruit	Yeast, *Bacillus* sp., *Acetobacter* sp., *Lactobacilus* sp.	Malaysia	Merican (1996)

Table 1.7 Some Common and Uncommon Ethnic Fermented Meat Products of the World

Product	*Substrate/Raw Materials*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Alheira	Pork or beef, bread chopped fat, spices, salt	Dry/ semi-dry, sausage	LAB, staphylococci, micrococci, yeast	Portugal	Albano et al. (2009)
Androlla	Ground lean pork	Dry, sausage	LAB, micrococci, yeast	Spain	Garcia-Fontan et al. (2007)
Arjia	Large intestine of chevon	Sausage, curry	*Ent. faecalis, Ent. faecium, Ent. hirae, Leuc. citreum, Leuc. mesenteroides, Ped. pentosaceus, Weissella cibaria*	India, Nepal	Oki et al. (2011)
Bacon	Cured pork, beef	Dry, semi-dry, staple	LAB, yeast, micrococci	Germany, Belgium, Spain	Tanaka et al. (1980)
Chartayshya	Chevon	Dried, smoked meat, curry	*Ent. faecalis, Ent. faecium, Ent. hirae, Leuc. citreum, Leuc. mesenteroides, Ped. pentosaceus, Weissella cibaria*	India	Oki et al. (2012)
Chorizo	Pork, coarse chopped, spices, salt	Dry	*Lb. sake, Lb. curvatus, Lb. plantarum*	Spain	Garcia-Varona et al. (2000)
Chilu	Yak, beef, sheep fat	Hard, oily, edible oil	LAB	India, China (Tibet), Bhutan	Tamang et al. (2009)
Ham	Cured pork	Semi-dry, breakfast	LAB, yeasts, micrococci	Spain, Italy	Simoncini et al. (2007)
Honoheigrain	Pig/boar meat	Rough, hard, dried meat; curry	*Lb. brevis, Lb. plantarum, Leuc. mesenteroides, E. faecium, B. cereus, B. pumilus, B. firmus, B. circulans, B. stearothermophilus, Micrococcus, Staphylococcus; Debaryomyces hansenii, Sacch. cerevisae*	India	Chakrabarty et al. (2014)

(*Continued*)

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Table 1.7 (*Continued*) Some Common and Uncommon Ethnic Fermented Meat Products of the World

Product	*Substrate/Raw Materials*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Kargyong	Yak, beef, pork, crushed garlic, ginger, salt	Sausage like meat product, curry	*Lb. sakei, Lb. divergens, Lb. carnis, Lb. sanfrancensis, Lb. curvatus, Leuc. mesenteroides, Ent. faecium, B. subtilis, B. mycoides, B. thuringiensis, Staph. aureus, Micrococcus* sp., *Deb. hansenii, Pic. anomala*	India	Rai et al. (2010)
Kheuri	Yak, beef	Chopped intestine of yak, curry	LAB	India, China (Tibet), Bhutan	Tamang et al. (2009)
Jerky	Beef	Dry, semi-dry, side dish	LAB, yeast, molds, micrococci	South America	Delong (1992)
Longanisa	Pork lean, pork backfat, ground pork, salt, sugar, soysauce, vinegar, anisado wine, potassium nitrate		LAB	Philippines	Alexandraki et al. (2013)
Mortadello	Pork	Unsmoked chopped meat, sausage	LAB, micrococci	Italy, France, USA	
Nham (Musom)	Pork meat, pork skin, salt, rice, garlic	Fermented pork	*Ped. cerevisiae, Lb. plantarum, Lb. brevis*	Thailand	Chokesajjawatee et al. (2009)

Nem-chua	Pork, salt, cooked rice	Fermented sausage	*Lb. pentosus, Lb. plantarum, Lb. brevis, Lb. paracasei, Lb. fermentum, Lb. acidipiscis, Lb. farciminis, Lb. rossiae, Lb. fuchuensis, Lb. namurensis, Lc. lactis, Leuc. citreum, Leuc. fallax, Ped. acidilactici, Ped. pentosaceus, Ped. stilesii, Weissella cibaria, W. paramesenteroides.*	Vietnam	Nguyen et al. (2011)
Pastirma	Chopped beef lean meat with lamb fat, not smoked, heavily seasoned	Dry/semi-dry, sausage	*Lb. plantarum, Lb. sake, Pediococcus, Micrococcus, Staph. xylosus, Staph. carnosus*	Turkey, Iraq	Aksu et al. (2005)
Peperoni	Pork, beef	Dried meat, smoked, sausage	LAB, micrococci	Europe, America, Australia	Adams (2010)
Salami	Pork	Sausage	LAB, micrococci	Europe	Adams (2010)
Sai-krok-prieo	Pork, rice	Sausage	LAB	Thailand	Phithakpol et al. (1995)
Soppressata	Chopped lean pork meat, NaCl and spices	Dry/ semi-dry, sausage	LAB, yeast, staphylococci, micrococci, enterobacteriaceae	Italy	Parente et al. (1994)
Salchichon	Pork or beef meat, fat, NaCl, spices	Dry, sausage	LAB, Yeast, micrococcaceae, enterobacteriaceae, molds	Spain	Fernandez-Lopez et al. (2008)
Salsiccia	Chopped pork meat, spices, NaCl	Dry/ semi-dry, sausage	LAB, yeast, enterobacteriaceae staphylococci, micrococci	Italy	Parente et al. (2001a,b)
Sucuk	Chopped meat, pork or beef, curing salts and various spices	Dry, sausage	LAB, micrococci, staphylococci, enterobacteriaceae	Turkey	Genccelep et al. (2008)

(*Continued*)

Table 1.7 (*Continued*) Some Common and Uncommon Ethnic Fermented Meat Products of the World

Product	*Substrate/Raw Materials*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Sai-krok-prieo	Pork, rice, garlic, salt	Fermented sausage	*Lb. plantarum, Lb. salivarius, Ped. pentosacuns*	Thailand	Adams (2010)
Satchu	Beef, yak, port, tumeric powder, edible oil, butter, salt	Ethnic dried meat, curry	*Ped. pentosaceuous, Lb. casei, Lb. carnis, Ent. faecium, B. subtilis, B. mycoides, B. lentus, Staph. aureus, Micrococcus* sp., *Deb. hansenii, Pic. anomala*	India	Tamang et al. (2012)
Suka ko masu	Goat, buffalo meat, tumeric powder, mustard oil, salt	Dried or smoked meat, curry	*Lb. carnis, Ent. faecium, Lb. plantarum, B. subtilis, B. mycoides, B. thuringiensis, Staph. aureus, Micrococcus* sp., *Debaromyces hansenii, Pic. burtonii*	India	Rai et al. (2010)
Sukula	Buffalo	Dried, smoked, curry	LAB	Nepal	Tamang (2010a)
Tocino	Pork, salt, sugar, potassium nitrate	Fermented cured pork	*Ped. cerevisiae, Lb. brevis, Leuc. mesenteroides*	Philippines	Alexandraki et al. (2013)

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Table 1.8 Some Common and Uncommon Ethnic Fermented Fish Products of the World

Product	*Substrate/Raw Materials*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Ayaiba	Fish	Smoked fish, pickle, curry	unknown	India	Tamang (2010a)
Bagoong Alamang (Bagoong Isda, Bagoong)	Fish/shrimp, salt	Fish/shrimp paste, condiment	*Bacillus* sp., *Pediococcus* sp.	Philippines	Alexandraki et al. (2013)
Balao-balao (Burong Hipon Tagbilao)	Shrimp, rice, salt.	Fermented rice shrimp, condiment	*Leuc. mesenteroides, Ped. cerevisiae, Lb. plantarum, Lb. brevis, Ent. faecalis*	Philippines	Alexandraki et al. (2013)
Balao-balao (Burong Hipon Tagbieao)	Shrimp, rice, salt	Fermented fish-rice, condiment	*Leuc. mesenteroides, Ped. cerevisiae*	Philippines	Arroyo et al. (1978)
Belacan (Blacan)	Shrimp, salt	Shrimp paste, condiment	*Bacillus, Pediococcus, Lactobacillus, Micrococcus, Sarcina, Clostridium, Brevibacterium, Flavobacterium, Corynebacteria*	Malaysia	Salampessy et al. (2010)
Bagoong	Fish	Fish paste; condiment	*Bacillus* sp., *Micrococcus* sp., *Moraxella* sp.	Philippines	Mabesa and Babaan (1993)
Bagoong alamang	Shrimp	Shrimp paste; condiment	LAB	Philippines	Mabesa and Babaan (1993)
Bakasang	Fish, shrimp	Fish or shrimp paste, condiment	*Pseudomonas, Enterobacter, Moraxella, Micrococcus, Streptococcus, Lactobacillus, Pseudomonas, Moraxella, Staphylococcus, Pediococcus* spp.	Indonesia	Ijong and Ohta (1996)

(*Continued*)

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Table 1.8 (*Continued*) Some Common and Uncommon Ethnic Fermented Fish Products of the World

Product	*Substrate/Raw Materials*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Burong Bangus	Milkfish, rice, salt, vinegar	Fermented milkfish, sauce	*Leuc. mesenteroides, Lb. plantarum, W. confusus*	Philippines	Alexandraki et al. (2013)
Burong Isda	Fish, rice, salt	Fermented fish, sauce	*Leuc. mesenteroides, Ped. cerevisiae, Lb. plantarum, Strep. faecalis, Micrococcus* sp.	Philippines	Sakai et al. (1983a,b)
Budu	Marine fishes, salt, sugar	Fish sauce	*Ped. halophilus, Staph. aureus, Staph. epidermidis, B. subtilis, B. laterosporus, Proteus* sp., *Micrococcus* sp., *Sarcina* sp., *Corynebacterium* sp.	Thailand, Malaysia	Merican (1977), Phithakpol et al. (1995)
Gnuchi	Fish (*Schizothorax richardsonii*), salt, tumeric powder	Eat as curry	*Lb. plantarum, Lact. lactis, Leuc. mesenteroides, Ent. faecium, Ent. faecalis, Ped. pentosaceus, Cand. chiropterorum, Cand. bombicola, Saccharomycopsis* sp.	India	Tamang et al. (2012)
Gulbi	Shell-fish	Salted and dried, side dish	*Bacillus licheniformis, Staphylococcus* sp., *Aspergillus* sp., *Candida* sp.	Korea	Kim et al. (1993)
Hákarl	Shark flesh	Fermented, side dish	LAB	Iceland	Alexandraki et al. (2013)
Hentak	Finger sized fish (*Esomus danricus*)	Condiment	*Lact. lactis, Lb. plantarum, Lb. fructosus, Lb. amylophilus, Lb. coryniformis, Ent. faecium, B. subtilis, B. pumilus, Micrococcus* sp., *Candida* sp., *Saccharomycopsis* sp.	India	Thapa et al. (2004)

Hoi-malaeng pu-dong	Mussel (*Mytilus smaragdinus*), salt	Fermented mussel	*Ped. halophilus*, *Staph. aureus*, *Staph. epidermidis*	Thailand	Phithakpol et al. (1995)
Ika-Shiokara	Squid, salt	Fermented squid	*Micrococcus* sp., *Staphylococcus* sp., *Debaryomyces* sp.	Japan	Alexandraki et al. (2013)
Jaadi	Fish, salt	Salted fish, curry, condiment	LAB	Sri Lanka	Alexandraki et al. (2013)
Jeot kal	Fish	High-salt fermented, staple	LAB	Korea	Guan et al. (2011)
Kapi	Small fish	Paste, condiment	Micrococci, LAB	Thailand	Phithakpol (1993)
Karati, Bordia, Lashim	Fish (*Gudushia chapra*, *Pseudeutropius atherinoides*, *Cirrhinus reba*), salt	Dried, salted, side dish	*Lact. lactis*, *Leuc. mesenteroides*, *Lb. plantarum*, *B. subtilis*, *B. pumilus*, *Candida* sp.	India	Thapa et al. (2007)
Kung-chom	Shrimp, salt, sweetened rice	Fermented fish-rice	*Ped. cerevisiae*	Thailand	Phithakpol (1993)
Kung chom	Shrimp (*Macrobrachum lanchesteri*), salt, garlic, rice	Fermented shrimp	*Ped. halophilus*, *Staph. aureus*, *Staph. epidermidis*	Thailand	Phithakpol (1993)
Kusaya	Horse mackerel, salt	Fermented dried fish	*Corynebacterium kusaya*, *Spirillum* sp., *C. bifermentans*, *Penicillium* sp.	Japan	Alexandraki et al. (2013)
Mehiawah	Marine fish	Fermented paste; side-dish		Middle-East	Al-Jedah et al. (1999)

(*Continued*)

Table 1.8 (*Continued*) Some Common and Uncommon Ethnic Fermented Fish Products of the World

Product	*Substrate/Raw Materials*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Myulchijeot	Small sardine, salt	Fermented small sardine	*Ped. cerevisiae*, *Staphylococcus* sp., *Bacillus* sp., *Micrococcus* sp.	Korea	Alexandraki et al. (2013)
Narezushi	Sea water fish, cooked millet, salt	Fermented fish-rice	*Leuc. mesenteroides*, *Lb. plantarum*	Japan	Alexandraki et al. (2013)
Nam pla (Nampla-dee, Nampla-sod)	*Solephorus* sp. *Ristelliger* sp. *Cirrhinus* sp., water, brackish water, marine fish, salt	Fish sauce	*Micrococcus* sp., *Pediococcus* sp., *Staphylococcus* sp., *Streptococcus* sp., *Sarcina* sp., *Bacillus* sp., *Lactobacillus* sp., *Corynebacterium* sp., *Pseudomonas* sp., *Halococcus* sp., *Halobacterium* sp.	Thailand	Saisithi (1987), Wongkhalaung (2004)
Ngari	Fish (puntius sophore), salt	Fermented fish	*Lact. lactis*, *Lb. plantarum*, *Ent. faecium*, *Lb. fructosus*, *Lb. amylophilus*, *Lb. coryniformis*, *B. subtilis*, *B. pumilus*, *Micrococcus* sp., *Candida* sp., *Saccharomycopsis* sp.	India	Thapa et al. (2004)
Nga pi	Fish	Fermented paste, condiment	LAB	Myanmar	Tyn (1993)
Ngan pyaye	Fish	Fish sauce, condiment	LAB	Myanmar	Tyn (1993)
Nuoc mam	Marine fish	Fish sauce, condiment	*Bacillus* sp., *Pseudomonas* sp., *Micrococcus* sp., *Staphylococcus* sp., *Halococcus* sp., *Halobacterium salinarium*, *H. cutirubrum*	Vietnam	Lopetcharat et al. (2001)

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Patis	*Stolephorus* sp., *Clupea* sp., *Decapterus* sp., *Leionathus* sp., fish, salt, food color-optional	Fish sauce	*Ped. halophilus, Micrococcus* sp., *Halobacterium* sp., *Halococcus* sp., *Bacillus* sp.	Philippines, Indonesia	Baens-Arega (1977)
Pla-ra	Fresh water fish, salt, roasted rice	Fermented fish-rice	*Pediococcus* sp.	Thailand	Phithakpol (1993)
Pla-chao (Pla-Khaomak)	Fresh water fish, salt, Khaomak	Thai sweetened fish	*Ped. cerevisiae, Staphyloccous* sp., *Bacillus* sp., *Micrococcus* sp.	Thailand	Phithakpol et al. (1995)
Pla-chom (Pla-khoa-kour)	Fresh water or marine anchovy, boiled rice, salt, garlic, roasted rice flour	Fermented fish, Thai anchovy	*Ped. cerevisiae, Lb. brevis, Bacillus* sp.	Thailand	Phithakpol et al. (1995)
Pekasam	Freshwater fish-rice	Fermented fish, side dish	LAB	Malaysia	Karim (1993)
Pindang	Fish	Dried, salted, side dish	LAB	Indonesia	Putro (1993
Pla-paeng-daeng	Marine fish, red molds rice (*Ang-kak*), salt	Red fermented fish	*Pediococcus* sp., *Ped. halophilus, Staph. aureus, Staph. epidermidis,*	Thailand	Phithakpol et al. (1995)
Pla ra (Pla-dag, Pla-ha, Ra)	Fresh water fish, brackish water fish, marine fish	Fermented fish	*Ped. cerevisiae, Lb. brevis, Staphylococcus* sp., *Bacillus* sp.	Thailand	Phithakpol et al. (1995)

(*Continued*)

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Table 1.8 (*Continued*) Some Common and Uncommon Ethnic Fermented Fish Products of the World

Product	*Substrate/Raw Materials*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Pla-som (Pla-khao-sug)	Marine fish, salt, boiled rice, garlic	Fermented fish	*Ped. cerevisiae, Lb. brevis, Staphylococcus* sp., *Bacillus* sp.	Thailand	Saithong et al. (2010)
Saeoo Jeot (Jeotkal)	Shrimp (*Acetes chinensis*), salt	Fermented shrimp	*Halobacterium* sp., *Pediococcus* sp.	Korea	Guan et al. (2011)
Som-fug (Som-dog, Pla-fu, Pla-muig, Fug-som)	Fresh fish, boiled rice, salt, garlic	Thai fermented fish, condiment	*Ped. cerevisiae, Lb. brevis, Staphylococcus* sp., *Bacillus* sp.	Thailand	Phithakpol et al. (1995)
Shottsuru	Anchovy, opossum shrimp, salt	Fish sauce, condiment	*Halobacterium* sp., *Aerococcus viridians (Ped. homari)*, halotolerant and halophilic yeasts	Japan	Itoh et al. (1993)
Sidra	Fish (*Punitus sarana*)	Dried fish, curry	*Lact. lactis, Lb. plantarum, Leuc. mesenteroides, Ent. faecium, Ent. facalis, Ped. pentosaceus, W. confusus, Cand. chiropterorum, Cand. bombicola, Saccharomycopsis* sp.	India	Thapa et al. (2006)
Sikhae	Sea water fish, cooked millet, salt	Fermented fish-rice, sauce	*Leuc. mesenteroides, Lb. plantarum*	Korea	Lee (1993)
Shiokara	Squid	Fermented; side-dish	LAB	Japan	Fujii et al. (1999)

Suka ko maacha	River fish (*Schizothorax richardsoni*), salt, turmeric powder	Smoked, dried, curry	*Lact. lactis, Lb. plantarum, Leuc. mesenteroides, Ent. faecium, Ent. faecalis, Ped. pentosaceus, Cand. chiropterorum, Cand. bombicola, Saccharomycopsis* sp.	India	Thapa et al. (2006)
Sukuti	Fish (*Harpodon nehereus*)	Pickle, soup, and curry	*Lact. lactis, Lb. plantarum, Leuc. mesenteroides, Ent. faecium, Ent. faecalis, Ped. pentosaceus, Cand. chiropterorum, Cand. bombicola, Saccharomycopsis* sp.	India	Thapa et al. (2006)
Surströmming	Fish	Fermented herrings	*Haloanaerobium praevalens*	Sweden	Kobayashi et al. (2000a)
Tai-pla	Fresh water fish, brackish water fish, marine fishes, salt	Fermented fish, condiment	*Pediococcus* sp., *Ped. halophilus, Staph. aureus, Staph. epidermidis*	Thailand	Phithakpol et al. (1995)
Trassi	Shrimps/fish	Fermented paste; side-dish	LAB, micrococci	Indonesia	Van Veen (1965)
Tungtap	Fish	Fermented fish, paste, pickle	*Lc. lactis* subsp. *cremoris, Lc. plantarum, Ent. faecium, Lb. fructosus, Lb. amylophilus, Lb. corynifomis* subsp. *Torquens, Lb. plantarum, B. subtilis, B. pumilus, Micrococcus*, yeasts-species of *Candida, Saccharomycopsis*.	India	Thapa et al. (2004)
Yu lu	Small fish like sardine or anchovies	Fish sauce	LAB, micrococci	China	Jiang et al. (2007)

reported from *surströmming*, the fermented herrings of Sweden and *Haloanaerobium fermentans, Tetra. muriaticus* and *Tetra. halophilus* from the Japanese puffer fish ovaries (Kobayashi et al. 2000b,c). *B. subtilis, B. pumilus, E. faecalis, E. faecium, Lc. lactis* subsp. *cremoris, Lc. lactis* subsp. *lactis, Lc. plantarum, Lb. amylophilus, Lb. fructosus, Lb. confusus, Lb.corynifomis* subsp. *torquens, Lb. plantarum, Leuc. mesenteroides, P. pentosaceus, Micrococcus*; yeasts—*Candida bombicola, C. chiropterorum,* and *Saccharomycopsis* spp. were isolated from Indian fermented and sun-dried fish products (Thapa et al. 2004, 2006, 2007).

1.5.9 Vinegar

Vinegar (Table 1.9) is one of the most popular condiments in the world and is prepared from any sugar containing substrates and hydrolyzed starchy materials by acetic acid fermentation. *Acetobacter aceti* subsp. *aceti, A. oryzae, A. pasteurianus, A. polyxygenes, A. xylinum, A. malorum, A. pomorum* are the dominant bacteria for vinegar fermentation (Haruta et al. 2006, Bourdichon et al. 2012). Yeast species in vinegar fermentation are *Candida lactis-condensi, C. stellata, Hanseniaspora valbyensis, H. osmophila, Saccharomycodes ludwigii, Sac. cerevisiae, Zygosaccharomyces bailii, Z. bisporus, Z. lentus, Z. mellis, Z. pseudorouxii*, and *Z. rouxii* (Solieri and Giudici 2008).

1.5.10 Ethnic Fermented Tea

Tea, the second most popular beverage in the world after water, originated in China and two common species of tea are *Camellia sinensis* var. *sinensis* and *Camellia sinensis* var. *assamica* (Schillinger et al. 2010). Though normal black tea is drunk everywhere, however, some ethnic Asian communities have special fermented tea such as *miang* of Thailand, *puer* tea and *fuzhuan brick* of China, and *kombucha*. Fermented tea (Table 1.10) is *puer tea, kombucha*, and *fuzuan* brick tea of China (Mo et al. 2008), and *miang* of Thailand (Tanasupawat et al. 2007).

Aspergillus niger is the predominant fungus in *puer tea*; *Blastobotrys adeninivorans, A. glaucus*, species of *Penicillium, Rhizopus* and *Saccharomyces*, and the bacterial species *Actinoplanes* and *Streptomyces* were also isolated from *puer tea* (Jeng et al. 2007, Abe et al. 2008). *Brettanomyces bruxellensis, Candida stellata, Rhodotorula mucilaginosa, Saccharomyces* spp., *Schizosaccharomyces pombe, Torulaspora delbrueckii, Zygosaccharomyces bailii, Z. bisporus, Z. kombuchaensis*, and *Z. microellipsoides* were isolated from *kombucha* (Kurtzuman et al. 2001, Teoh et al. 2004). The major bacterial genera present in *kombucha* were *Gluconacetobacter* (>85%), *Acetobacter* (<2%), *Lactobacillus* (up to 30%), and the yeast populations were found to be dominated by *Zygosaccharomyces* (>95%) (Marsh et al. 2014). *Lb. thailandensis, Lb. camelliae, Lb. plantarum, Lb. pentosus, Lb. vaccinostercus, Lb. pantheris, Lb. fermentum, Lb. suebicus, Ped. siamensis, E. casseliflavus*, and *E. camelliae* are involved in the fermentation of *miang* production (Sukontasing et al. 2007, Tanasupawat et al. 2007). Species of *Aspergillus, Penicillium* and *Eurotium* are major fungi for fermentation of *fuzhuan brick* tea (Mo et al. 2008).

1.5.11 Bacterial Cellulose

Nata or bacterial cellulose (Table 1.10) produced by *Acetobacter xylinum* is a candied delicacy of the Philippines (Kozaki 1976, Jagannath et al. 2010, Adams 2014). Two types of *nata* are well known: *nata de piña,* produced from the juice from pineapple trimmings, and *nata de coco,* produced from coconut water or coconut skim milk. Species identification using 16S rDNA sequencing revealed that the two strains belong to two different species of

Table 1.9 Some Common and Uncommon Vinegar Products of the World

Product	*Substrate*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Cuka Aren	Sap from flower stalk of Aren	Vinegar, seasoning	*Acetobacter* sp.	Indonesia	Alexandraki et al. (2013)
Cuka Nipah	Sap from inflorescence stalk of Nipa fruiticans	Vinegar, seasoning	*Acetobacter* sp.	Malaysia	Alexandraki et al. (2013)
Sirca	Gur of molasses or grains	Vinegar, seasoning	*Sacch. cerevisiae, Acetobacter* sp.	Pakistan	Alexandraki et al. (2013)
Sirka	Fruit juices or sugar cane juices	Vinegar, seasoning	*Acetobacter* sp.	Bangladesh	Alexandraki et al. (2013)
Suka	Coconut water or fruits or sugar or palm sap or rice washings	Vinegar, seasoning	*Lb. fermentum, Lb. plantarum, Lb. panis, Lb. pontis, W. cibaria, Acetobacter pomoum, Actobacter ghanensis, Acetobacter orientalis, Acetobacter pasteurianus*	Philippines	Dalmacio et al. (2011)
Vinegar	Sugar containing substrates	Acetic acid flavored, liquid, condiment, seasoning	*Acetobacter aceti* subsp. *aceti, A. oryzae, A. pasteurianus, A. polyxygenes, A. xylinum, A. malorum, A. pomorum; Candida lactis-condensi, C. stellata, Hanseniaspora valbyensis, H. osmophila, Saccharomycodes ludwigii, Sacch. cerevisiae, Zygosaccharomyces bailii, Z. bisporus, Z. lentus, Z. mellis, Z. pseudorouxii, Z. rouxii*	Worldwide	Solieri and Giudici (2008), Sengum and Karabiyikli (2011)

Table 1.10 Some Miscellaneous Fermented Products of the World

Fermented Products	*Substrate/Raw Materials*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Fermented Tea					
Fuzhuan brick	Tea	Fermented tea, drink	*Aspergillus, Penicillium, Eurotium*	China	Mo et al. (2008)
Kombucha or Tea fungus	Tea liquor	Flavored, drink	*Acetobacter xylinum, Zygosaccharomyces kombuchaensis, Z. bailii, Z. bisporus, Z. microellipsoides, Brettanomyces, Saccharomyces, Schizosaccharomyces pombe, Torulaspora delbrueckii, Rhodotorula mucilaginosa, Candida stellata, Brettanomyces bruxellensis*	China (Tibet), India	Schillinger et al. (2010)
Miang	Tea	Fermented tea, flavored, drink	*Lb. thailandensis, Lb. camelliae, Lb. plantarum, Lb. pentosus, Lb. vaccinostercus, Lb. pantheris, Lb. fermentum, Lb. suebicus, Pediococcus siamensis, E. casseliflavus* and *E. camelliae*	Thailand	Tanasupawat et al. (2007)
Puer	Tea	Fermented tea, brownish red, and a fragrance produced, drink	*Asp. glaucus*, species of *Penicillium*, and *Rhizopus, Blastobotrys adeninivorans*, and *Saccharomyces Actinoplanes, Streptomyces*	China	Jeng et al. (2007), Abe et al. (2008)
Bacterial Cellulose					
Nata de coco	Coconut water or coconut skim milk	Thick white or cream-colored, candied, ice cream, fruit salads	*Acetobacter* xylinus and A. hansenii	Philippines	Bernardo et al. (1998)

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Nata de piña	Juice from pineapple	Insoluble gelatinous film of polysaccharides, ice cream, fruit salads	*Acetobacter* xylinus and A. hansenii	Philippines	Bernardo et al. (1998)
Chocolate					
Cacao	Cacao beans in pods of tree *Theobroma cocao*	Chocolate, confectionery	*Lb. fermentum, Acetobacter pasteurianus, A. senegalensis, Lb. ghanensis, Lb. plantarum, Lb. cacaonum, Lb. fabifermentans, Weissella fabaria, W. ghanensi, Fructobacillus pseudoficulneus, Tatumella ptyseos, Tatumella citrea, Bacillus coagulans; Hanseniaspora uvarum, H. quilliermundii, Issatchenkia orientalis (Candida krusei*), *Pichia membranifaciens, Sacch. cerevisiae, Kluyveromyces* sp.	Worldwide	Papalexandratou et al. (2011)
Coffee					
Coffee	Coffee	Flavored coffee, refreshing drink	*Ent. cloacae, Klebsiella oxytoca, Hafnia alvei, Lactobacillus, Leuconostoc, Weissella* spp.	Worldwide	Holzapfel and Müller (2007), Schillinger et al. (2008)
Fermented egg					
Pidan	Duck egg	Alkaline, side dish	*B. cereus, B. macerans, Staphylococcus cohnii, Staph. epidermidis, Staph. haemolyticus, Staph. warneri*	China	Wang and Fung (1996)

Acetobacter: A. xylinus and *A. hansenii* and may be a new subspecies under these species designation (Bernardo et al. 1998). Bacterial cellulose, a microbial polysaccharide, has significant potential as a food ingredient in view of its high purity, *in situ* change of flavor and color, and its ability to form various shapes and textures (Shi et al. 2014).

1.5.12 Cocoa/Chocolates

Chocolate (Table 1.10) is also a fermented product obtained from cocoa beans which require fermentation as one of the first stages. *Lb. fermentum* and *Acetobacter pasteurianus* were the predominating bacterial species during cocoa fermentation (Lefeber et al. 2010, Papalexandratou et al. 2011). Diverse LAB species appear to be typically associated with the fermentation of cocoa beans in Ghana, and, in fact, a number of new species have been described in recent years, for example, *Lb. ghanensis* (Nielsen et al. 2007), *Weissella ghanensis* (de Bruyne et al. 2008), *Lb. cacaonum, Lb. fabifermentans* (de Bruyne et al. 2009) and *Weissella fabaria* (de Bruyne et al. 2010). *Fructobacillus pseudoficulneus, Lb. plantarum*, and *Acetobacter senegalensis* were among the prevailing species during the initial phase of cocoa fermentation, and *Tatumella ptyseos* and *Tatumella citrea* were the prevailing enterobacterial species in the beginning of the fermentation (Papalexandratou et al. 2011). *Bacillus coagulans* are also recovered in vinegar (Bourdichon et al. 2012). Yeasts involved during spontaneous cocoa fermentation are *Hanseniaspora uvarum, H. quilliermundii, Issatchenkia orientalis* (*Candida krusei*), *Pichia membranifaciens, Sacch. cerevisiae,* and the *Kluyveromyces* species for flavor development (Ardhana and Fleet 1989).

1.5.13 Coffee Cherries

Coffee cherries are harvested from *Coffea arabica* trees and are processed by either wet or dry methods to remove the pulp and mucilaginous materials that surround the seeds (Silva et al. 2008). Species of yeasts and bacteria grow throughout these processes, producing pectinolytic, hemicellulolytic, and other enzymes that facilitate pulp and mucilage degradation (Masoud et al. 2004). *Ent. cloacae, Klebsiella oxytoca,* and *Hafnia alvei* have been isolated from coffee berries of Ethiopia (Holzapfel and Müller 2007), while LAB represented by *Lactobacillus, Leuconostoc*, and *Weissella* spp. seem to be typically associated with desirable fermentations of the coffee cherry (Schillinger et al. 2008).

1.5.14 Fermented Eggs

Pidan (Table 1.10), consumed by the Chinese, are preserved eggs prepared from alkali-treated fresh duck eggs, which have a strong smell of hydrogen sulfide and ammonia (Ganasen and Bejakul 2010). The main alkaline chemical reagent used for making *pidan* is sodium hydroxide, which is produced by the reaction of sodium carbonate, water, and calcium oxide of pickle or coating mud. *B. cereus, B. macerans, Staphy. cohnii, Staph. epidermidis, Staph. haemolyticus*, and *Staph. warneri* are predominant in *pidan* (Wang and Fung 1996).

1.6 Types of Fermented Beverages

1.6.1 Amylolytic Mixed Starters

The production of amylolytic starters (Table 1.11) are a unique traditional technology of preservation of the essential consortia of microorganisms (filamentous molds, amylolytic and

Table 1.11 Some Ethnic Amylolytic Starter Cultures of Asia

Product	*Substrate*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Balan	Wheat	Dry, ball-like starter	Molds, yeasts	India	Tamang (2010a)
Bakhar	Rice-herbs	Dry, ball-like starter	Yeasts	India	Tamang (2010a)
Budod	Rice, starter	Basi production	*Mu. circinelloides, Mu. grisecyanus, Rhi. cohnii, Sacch. cerevisiae, Saccharomycopsis fibuligera*	Philippines	Kozaki and Uchimura (1990)
Binubudan (Binuburan, Purad)	Milled rice + Budod	Basi production	*Debarymyces hansenni, Cand. parapsilosis, Trichosporon fennicum*	Philippines	Tanimura et al. (1978)
Binokhok	Roast rice	Starter	Unknown	Philippines	Alexandraki et al. (2013)
Chiu-yueh	Rice, wild herbs	Gray-white, dry ball to preparae *lao-chao*	Species of *Rhizopus, Amylomyces, Torulopsis, Hansenula*	China, Taiwan, Singapore	Wei and Jong (1983)
Chou or *chu* or *shi* or *qu*	Rice, wheat, sorghum or barley flour	Dry, ball, cake or brick shaped	Species of Aspergillus, Candida, Weissella, Staphylococcus	China	Yan et al. (2013)
Chuzo	Rice, wild herbs	Dry, ball-like starter	Molds, yeasts, LAB	Mongolia	Alexandraki et al. (2013)
Dabai	Rice, wild herbs	Dry, ball-like starter	Molds, yeasts, LAB	India	Sha et al. (2012)

(*Continued*)

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Table 1.11 (*Continued*) Some Ethnic Amylolytic Starter Cultures of Asia

Product	*Substrate*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Hamei	Rice	Starter to make *atingbai*	*Mucor* sp., *Rhizopus* sp., *Sacch. cerevisiae*, *Pic. anomala*	India	Jeyaram et al. (2008b)
Hong qu (*hóng qu*)	Rice	Starter to make Chinese wine	*Saccharomycopsis fibuligera*, *Sacch. cerevisiae*, *Pichia*, *Candida*, *Cryptococcus*, *Rhodotorula*, *Sporobolomyces*, *Rhodosporidium*	China	Lv et al. (2013)
Humao	Rice, barks of wild plants	Dry, flat, cake-like starter for *Judima* production	*Ped. Pentosaceous*, *B. polymyxa*, *B. licheniformis*, *B. stearothermophilus*, *D. hansenii*, *Sacch. cerevisiae*, *Rhizopus*, *Mucor*	India	Chakrabarty et al. (2014)
Jui paing	Rice, wild herbs	Dry, ball-like starter to preparae *tapai*	Molds, yeasts, LAB	Malaysia	Alexandraki et al. (2013)
Ipoh/Siye	Rice, wild herbs	Dry, mixed starter	Molds, yeasts, LAB	India	Tamang (2010a)
Koji	Rice, wheat	Dry, black-yellow colored, mold-culture to produce *saké*, *miso*, *shoyu*	*Asp. awamori*, *Asp. kawachii*, *Asp. oryzae*, *Asp. shirousamii*, *Asp. Sojae*, yeasts	Japan	Lee et al. (2007), Suganuma et al. (2007)
Khekhrii	Germinated rice	Dry starter to make *Zutho*	Yeasts, LAB	India	Tamang (2010a)
Loogpang	Rice flour, powder of Kha root, spices	Starter, cake	*Rhizopus* sp., *Mucor* sp., *Chlamydomucor* sp., *Penicillum* sp., *Aspergillus* sp., *Asp. niger*, *Asp. flavus*, *Endomycopsis* sp., *Hansenula* sp., *Saccharomyces* sp.	Thailand	Tamang (2012b)

Marcha	Glutinous rice, roots, wild herbs, ginger, red dry chili	Starter	*Mu. circinelloides, Mu. hiemalis, Rhiz. chinensis, Rhiz. stolonifer, Saccharomycopsis fibuligera, Saccharomycopsis capsularis, Pichia anomala, Pichia burtonii, Sacch. cerevisiae, Sacch. bayanus, Cand. glabrata, Ped. pentosaceus, Lb. bifermentans, Lb. brevis*	India	Tsuyoshi et al. (2005)
Mana	Wheat, herbs	Dry, granulated starter to produce alcoholic drinks	*Asp. oryzae, Rhizopus* spp.	Nepal	Nikkuni et al. (1996)
Manapu	Rice-wheat, herbs	Dry, mixed starter to produce *poko*	Molds, yeasts	Nepal	Shrestha et al. (2002)
Men	Rice, wild herbs, spices	Dry, ball-like starter to produce *Ruou*	*Rhi. oryzae, Rhi. microsporus, Absidia corymbifera, Amylomyces rouxii, Saccharomycopsis fibuligera, Sacch. cerevisiae, Issatchenkia* sp., *Pic. anomala, Pic. ranongensis, Candida tropicalis, Clavispora lusitaniae, Xeromyces bisporus, Botryobasidium subcoronatum*; *Ped. pentosaceus, Lb. plantarum, Lb. brevis, Weissella confusa, W. paramesenteroides, Bacillus subtilis, B. circulans, B. amyloliquefaciens, B. sporothermodurans, Acetobacter orientalis, A. pasteurianus, Burkholderia ubonensis, Ralstonia solanacearum, Pelomonas puraquae*	Vietnam	Dung et al. (2006), Thanh et al. (2008)
Meju	Soybean	Fermented soybean starter	*Asp. oryzae, B. subtilis*	Korea	Alexandraki et al. (2013)

(*Continued*)

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Table 1.11 (*Continued*) Some Ethnic Amylolytic Starter Cultures of Asia

Product	*Substrate*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Nuruk (Kokja)	Wheat	Starter to produce *Takju, sojo, yakju*	*Asp. oryzae, Candida* sp., *Asp. niger, Rhizopus* sp., *Penicillum* sp., *Mucor* sp., *Hansenula anomala, Leuc. mesenteroides, B. subtilis*	Korea	Jung et al. (2012)
Phab	Wheat, wild herbs	Dry, mixed starter to produce *chyang*	Molds, yeasts, LAB	India, China (Tibet), Bhutan, Nepal	Tamang (2010a)
Poo	Rice, herbs	Dry, mixed starter to produce *chyang*	Molds, yeasts, LAB	Bhutan	Tamang (2012b)
Ragi	Rice flour, spices	Starter to produce *tape*	*Rhizopus, Mucor, Amylomyces rouxii, Aspergillus, Saccharomycopsis, Candida parapsilosis, C. melinii, C. lactosa, C. pelliculosa, Sacch. cerevisiae, Hansenula subpelliculosa, H. anomala* and *H. malanga, Enterococcus faecalis, Lb. plantarum* and *Ped. pentosaceus, B. coagulans, B. brevis, B. stearothermophilus*	Indonesia	Hesseltine et al. (1988), Hesseltine and Ray (1988)

Samac	Sugar cane	Basi production	Yeast, bacteria, molds	Philippines	Alexandraki et al. (2013)
Thiat	Rice-herbs	Dry, mixed starter to produce *kiad-lieh*	Molds, yeasts, LAB	India	Tamang (2010a)
Torami	Rice	Fermented rice gruel	*Hansenlu anomala, Candida guilliermondii, C. tropicalis, Geotrichium candidum*	India	Batra and Millner (1974)
Yao Qu (yào qu)	Rice	Starter to make Chinese wine	*Saccharomycopsis fibuligera, Sacch. Cerevisiae, Pichia, Candida, Cryptococcus, Rhodotorula, Sporobolomyces, Rhodosporidium*	China	Lv et al. (2013)

alcohol-producing yeasts, and LAB) with rice or wheat as the base in the form of dry, flat or round balls, for the production of alcoholic beverages in South East Asia including the Himalayan regions of India, Nepal, and Bhutan (Tamang 2010a). Three types of dry, amylolytic and mixed cultures or inocula are traditionally used in Asia as starters to convert cereal starch to sugars and subsequently to alcohol and organic acids (Tamang and Fleet 2009):

1. A consortium of mycelial or filamentous molds, amylolytic and alcohol-producing yeasts and LAB with rice or wheat as the base in the form of dry, flat or round balls of various sizes. The starter is inoculated with a previous starter. This mixed flora is allowed to develop for a short time, then dried, and used to make either alcohol or fermented foods from starchy materials, for example, *marcha, ragi, bubod, loogpang, nuruk, men,* and so on (Tamang 2010c), which are used as starters for a number of fermentations based on rice and cassava or other cereals in Asia (Table 1.12).
2. A combination of *Aspergillus oryzae* and *A. sojae* is used in the form of a starter called *koji* in Japan to produce alcoholic beverages including *saké. Koji* also produces amylases that convert starch into fermentable sugars, which are then used for the second stage yeast fermentation to make nonalcoholic fermented soybean products called *miso* and *shoyu,* while proteases are formed to break down the soybean protein.
3. Whole-wheat flour is moistened and made into large compact cakes, which are incubated to culture yeasts and filamentous molds and are used to ferment starchy material to produce alcohol in China.

Asian amylolytic starters have different vernacular names such as *marcha* in India and Nepal, *hamei, humao, phab* in India (Tamang et al. 1996, 2012; Shrestha et al. 2002), *mana* and *manapu* in Nepal (Nikkuni et al. 1996), *men* in Vietnam (Dung et al. 2007), *ragi* in Indonesia (Uchimura et al. 1991), *bubod* in the Philippines (Hesseltine and Kurtzman 1990), *chiu/chu* in China and Taiwan (Steinkraus 1996), *loogpang* in Thailand (Vachanavinich et al. 1994), and *nuruk* in Korea (Steinkraus 1996).

Microbial profiles of Indian amylolytic starters are filamentous molds—*Mucor circinelloides* forma *circinelloides, Mu. hiemalis, Rhi. chinensis*, and *Rhi. stolonifer* variety *lyococcus* (Tamang et al. 1988), yeasts—*Sacch. cerevisiae, Sacch. bayanus, Saccharomycopsis* (*Sm.*) *fibuligera, Sm. capsularis, Pichia anomala, Pic. burtonii,* and *Candida glabrata* (Tamang and Sarkar 1995, Tsuyoshi et al. 2005, Tamang et al. 2007, Jeyaram et al. 2008b, 2011), and LAB—*Ped. pentosaceus, Lb. bifermentans*, and *Lb. brevis* (Hesseltine and Ray 1988, Tamang and Sarkar 1995, Tamang et al. 2007). Microorganisms in *men* of Vietnam include amylase producers (*Rhi. oryzae, Rhi. microsporus, Absidia corymbifera, Amylomyces rouxii, Saccharomycopsis fibuligera*), ethanol producers (*Sacch. cerevisiae, Issatchenkia* sp., *Pic. anomala, Pic. ranongensis, Candida tropicalis, Clavispora lusitaniae*), yeasts contaminants (*Xeromyces bisporus, Botryobasidium subcoronatum*); LAB (*Ped. pentosaceus, Lb. plantarum, Lb. brevis, Weissella confusa, W. paramesenteroides*), amylase-producing bacilli (*Bacillus subtilis, B. circulans, B. amyloliquefaciens, B. sporothermodurans*), acetic acid bacteria (*Acetobacter orientalis, A. pasteurianus*), and environmental contaminants (*Burkholderia ubonensis, Ralstonia solanacearum, Pelomonas puraquae*) (Dung et al. 2006, 2007, Thanh et al. 2008).

A combination of *Asp. oryzae* and *Asp. sojae* are used in *koji* in Japan to produce alcoholic beverages including *saké* (Zhu and Trampe 2013). *Koji* (Chinese *chu, shi,* or *qu*) also produces amylases that convert starch into fermentable sugars, which are then used for the second stage yeast fermentation to make nonalcoholic fermented soybean *miso* and *shoyu* (Sugawara 2010). *Asp. awamori, Asp. kawachii, Asp. oryzae, Asp. shirousamii*, and *Asp. sojae* have been widely used as the

Table 1.12 Some Common and Uncommon Ethnic Fermented Beverages and Alcohol Drinks of the World

Product	*Substrate*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Aara	Cereals	Clear distilled liquor	Unknown	India	Tamang (2010a)
Aarak	Barley, millet, *phab*	Distilled from *chyang*, clear liquor	Unknown	India, China (Tibet), Bhutan	Tamang (2010a)
Arrakku	Palm sap, sugar	Palm wine	*Sacch. cerevisiae*	Sri Lanka	
Atingba	Rice, *hamei*	Mild-alcoholic, sweet-sour		India	Jeyaram et al. (2009)
Apong	Rice, *phab*	Mild-alcoholic		India	Chakrabarty et al. (2014)
Bantu beer	Sorghum, millet	Opaque appearance, sour flavor, beer	LAB, yeasts	South Africa	Kutyauripo et al. (2009)
Basi	Sugar cane, *bubod*	Clear or cloudy liquid	Yeasts, molds	Philippines	Tanimura et al. (1978)
Bhaati Jaanr	Glutinous rice, *marcha*	Fermented rice beverage	*Mu. circinelloides, Rhiz. chinensis, Sm. fibuligera, Pic. anomala, Sacch. cerevisiae, Cand. glabrata, Ped. pentosaceus, Lb. bifermentans*	India	Tamang and Thapa (2006)
Bhang-chyang	Maize-rice/barley, *phab*	Extract of *mingri*, alcoholic beverage	Yeasts, molds	India	Thakur
Brem	Glutinous rice, ragi	Alcoholic drink	*Sacch. cerevisiae, Cand. glabrata, Cand. parapsilosis P. anomala, Issatchenkia arientalis, Lactobacillus* sp., *Acetobacter* sp. *Mu. indicus,*	Indonesia	Sujaya et al. (2004)

(*Continued*)

Health Benefits of Fermented Foods and Beverages

Table 1.12 (*Continued*) Some Common and Uncommon Ethnic Fermented Beverages and Alcohol Drinks of the World

Product	*Substrate*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Bouza	Wheat, malt	Alcoholic thin gruel, alcoholic drink	LAB	Egypt	Steinkraus (1996)
Boza	Wheat, rye, millet, maize	Cooked slurry, food beverage	LAB, yeasts	Bulgaria, Romania, Turkey, Albania	Steinkraus (1996)
Bussa	Maize, sorghum, finger millet	Alcoholic thin gruel, refreshing drink	Yeasts, LAB	Kenya	Steinkraus (1996)
Bushera	Sorghum, millet	Slurry, food beverage	Yeasts, LAB	Uganda	Steinkraus (1996)
Bupju	Rice, glutinous rice, water, starter (Nuruk)	Alcoholic beverage	*Saccharomyces* sp.	Korea	Jung et al. (2012)
Cauim	Cassava, rice, peanuts, pumpkin, cotton seed, maize	Alcoholic beverage	Lb. plantarum, Lb. fermentum, Lb. paracasei, Lb. brevis; Pic. guilliermondii, K. lactis, Candida sp, Rhi. toruloides, Sacch. cerevisiae	Brazil	Ramos et al. (2010)
Chyang/Chee	Finger millet/barley, *phab*	Mild-alcoholic, slightly sweet-acidic		China (Tibet), Bhutan, Nepal, India	Tamang (2010a)
Chicha	Maize, human saliva	Alcoholic drink	*Sacch. cerevisiae, Sacch. apiculata, Sacch. pastorianus*, species of *Lactobacillus, Acetobacter*	Peru	Vallejo et al. (2013)
Chulli	Apricot	Filtrate, clear, alcoholic drink	Yeast	India	Thakur et al. (2004)

Daru	Cereal	Alcoholic beverages; filtrate, jiggery	Yeast, LAB	India	Thakur et al. (2004)
Emu	Palm	Palm wine, submerged	*Sacch. cerevisiae, Schizosaccharomyces pombe, Lb. plantarum, Leuc. mesenteroides*	West Africa	Odunfa and Oyewole (1997)
Ennog	Rice, paddy husk	Black rice beer	Yeast, LAB	India	Tamang (2010a)
Ewhaju	Rice, *nuruk*	Nondistilled, filtered and clarified, clear liquor	Yeast, LAB	Korea	Jung et al. (2012)
Faapar ko jaanr	Buck wheat, *marcha*	Mild-acidic, alcoholic beverage		India, Nepal	Tamang (2010a)
Feni	Cashew apple	Distilled wine from cashew apples, strong flavor	*Sacch. cerevisiae*	World-wide	Tamang (2010c)
Gahoon ko jaanr	Wheat, *marcha*	Mild-acidic, alcoholic beverage		India, Nepal	Tamang (2010a)
Haria	Rice, *dabai*	Alcoholic beverage	*Sacch. cerevisiae, Sacch. boulardii, Zygosaccharomyces cidri, Candida tropicalis, C. musae, C. nitratophila, Issatchenkia* sp., *Pediococcus* sp., *Lactobacillus* sp.	India	Sha et al. (2012)
Jao ko jaanr	Barley, *marcha*	Mild-acidic, alcoholic beverage	Yeast, molds, *Pediococcus*	India, Nepal	Tamang (2010a)
Jou	Rice	Mild-alcoholic beverage	Yeasts, LAB	India	Tamang (2010a)

(*Continued*)

Table 1.12 (*Continued*) Some Common and Uncommon Ethnic Fermented Beverages and Alcohol Drinks of the World

Product	*Substrate*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Kaffir beer (same as *Bantu beer)*	Sorghum, millet	Opaque appearance, sour flavor, beer	LAB, yeasts	South Africa	Tamang (2010c)
Kanji	Carrot/beet roots, *Torani*	Strong flavored, alcoholic drink	*Hansenlu anomala, Candida guilliermondii, C. tropicalis, Geotrichium candidum, Leuc. mesenteroides, Pediococcus* spp., *Lb. dextranicum, Lb. paraplantarum, Lb. pentosus*	India	Sura et al. (2001), Kingston et al. (2010)
Khao maak	Rice, *loogpang*	Juicy, white colored, sweet taste, mild alcoholic dessert	LAB, yeasts	Thailand	Phithakpol et al. (1995)
Kiad lieh	Rice, *thiat*	Distilled liquor, clear, alcoholic drink	LAB, yeasts	India	Tamang (2010a)
Krachae	Rice, *loogpang*	Nondistilled and filtered liquor	Molds, yeasts	Thailand	Vachanavinich et al. (1994)
Kodo Ko Jaanr	Millet	Alcoholic liquor	*Mu. circinelloides, Rhiz. Chinensis, Sm. fibuligera, P. anomala, Sacch. cerevisiae, Cand. glabrata, Ped. pentosaceus, Lb. bifermentans*	India, Nepal	Thapa and Tamang (2004)
Judima	Rice	Alcoholic beverage	*Ped. pentosaceous, B. circulans, B. laterosporus, B. pumilus, B. firmus; D. hansenii, Sacch. cerevisiae*	India	Chakrabarty et al. (2014)
Lohpani	Maize-rice, barley	Alcoholic liquor, beverage	Unknown	India	Tamang (2010a)

Lugri	Barley, *phab*	Sweet-sour, mild alcoholic, thick liquid, alcoholic beverage	Yeasts, molds	India, China (Tibet)	Thakur et al. (2004)
Madhu	Rice	Distilled liquor, alcoholic drink	Yeasts, molds	India	Tamang (2010a)
Makai ko jaanr	Maize, marcha	Mild-alcoholic, sweet-sour beverage	Yeast, molds, *Pediococcus*	India, Nepal	Tamang (2010a)
Makgeolli	Rice, *nuruk*	Mild-alcoholic, sweet-sour beverage	Family-Saccharomycetaceae γ-*Proteobacteria* to *Firmicutes*	Korea	Jung et al. (2012)
Mangisi	Maize	Liquor, alcoholic drink	Yeast, LAB	Zimbabwe	Tamang (2010c)
Mbege	Malted millet	Acidic, mild-alcoholic, drink	Yeast, LAB	Tanzania	Tamang (2010c)
Merrisa	Millet, cassava	Turbid drink, beer	Yeasts, LAB	Sudan	Tamang (2010c)
Mingri	Maize-rice/barley	Sweet, mild alcoholic, thick, beverage	*Phab*	India	Thakur et al. (2004)
Nam khao	Rice, *loogpang*	Distilled liquor, alcoholic drink		Thailand	Phithakpol et al. (1995)
Nareli	Coconut palm	Sweet, milky, effervescent, mild alcoholic beverage	Yeasts, LAB	India	Tamang (2010a)
Nchiangne	Red rice, *khekhrii*	Distilled liquor, alcoholic drink	Yeasts, LAB	India	Tamang (2010a)
Oh	Rice-millet	Soft, mild-alcoholic beverage	Unknown	India	Tamang (2010a)
Ou	Rice, *loogpang*	Distilled liquor, alcoholic drink	Yeasts, LAB	Thailand	Phithakpol et al. (1995)

(*Continued*)

Health Benefits of Fermented Foods and Beverages

Table 1.12 (*Continued*) Some Common and Uncommon Ethnic Fermented Beverages and Alcohol Drinks of the World

Product	*Substrate*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Toddy/tari	Palm sap	Palm wine, sweet, milky, effervescent and mild alcoholic beverage	*Sacch. cerevisiae, Schizosaccharomyces pombe, Acetobacter aceti, A. rancens, A. suboxydans, Leuc. dextranicum, Micrococcus* sp., *Pediococcus* sp., *Bacillus* sp., *Sarcina* sp.	India	Shamala and Sreekantiah (1988)
Poko	Rice, *manapu*	Sweet-acidic, mild-alcoholic beverage	Yeasts, molds, LAB	Nepal	Shrestha et al. (2002)
Pona	Rice	Mild-alcoholic, sweet-sour, paste	Molds, yeast, LAB	India	Tamang (2010a)
Pulque	Agave juice	White, viscous, acidic-alcoholic, refreshing drink	*Lc. lactis* subsp. *lactis, Lb. acetotolerans, Lb. acidophilus, Lb. hilgardii, Lb. kefir, Lb. plantarum, Leuc. citreum, Leuc. kimchi, Leuc. mesenteroides, Leuc. pseudomesenteroides, Erwinia rhapontici, Enterobacter* spp., *Acinetobacter radioresistens, Zymomonas mobilis, Acetobacter malorum, A. pomorium, Microbacterium arborescens, Flavobacterium johnsoniae, Gluconobacter oxydans, Hafnia alvei, Sacch. bayanus, Sacch. cerevisiae, Sacch. Paradoxus, Candida* spp., *C. parapsilosis, Clavispora lusitaniae, Hanseniaspora uvarum, Kl. lactis, Kl. marxianus, Pic. membranifaciens, Pic.* spp., *Torulaspora delbrueckii*	Mexico	Escalante et al. (2008), Lappe-Oliveras et al. (2008)

Raksi	Cereals, *marcha*	Clear distilled liquor , alcoholic drink	Molds, LAB	India, Nepal	Kozaki et al. (2000)
Ruou de	Rice, *men*	Distilled liquor, clear, alcoholic drink	Molds, LAB	Vietnam	Dung (2004)
Ruou nep	Rice, *men*	Distilled liquor, clear, alcoholic drink	Molds, LAB	Vietnam	Dung (2004)
Ruou nep than	Rice (purple), *men*	Nondistilled, viscous, thick food beverage	Molds, LAB	Vietnam	Dung (2004)
Ruou nep chan	Rice, maize, cassava, *men*	Nondistilled, viscous, thick; or distilled, alcoholic drink	Molds, LAB	Vietnam	Dung (2004)
Ruhi	Rice	Distilled liquor, alcoholic beverage	Yeasts	India	Tamang (2010a)
Roselle wine	Roselle fruit, water, sugar	Roselle wine	*Sacch. ellipsoideus* var. *montrachet*	Philippine	Tamang (2010c)
Saké	Polished rice, glucose, *koji*	Nondistilled, clarified, and filtered liquor, alcoholic drink	*Asp. oryzae, Sacch. cerevisiae, Lb. sakei, Leuc. mesenteroides*	Japan	Kotaka et al. (2008)
Sato	Rice, *loogpang*	Distilled liquor, alcoholic drink	Yeasts, molds	Thailand	Phithakpol et al. (1995)
Seketch	Maize	Alcoholic beverage	*Sacch. cerevisiae, Sacch. chevalieri, Sacch. elegans, Lb. plantarum, Lc. lactis, B. subtilis, Asp. niger, Asp. flavus, Mu. Rouxii*	Nigeria	Blandino et al. (2003)
Shochu/soju	Rice, sweet potato, barley, millet, corn, *koji*	Distilled spirit, alcoholic drink	*Asp. awamorii, Asp. kawachii, Sacch. cerevisiae*	Japan	Steinkraus (1996)

(*Continued*)

Health Benefits of Fermented Foods and Beverages

Table 1.12 (*Continued*) Some Common and Uncommon Ethnic Fermented Beverages and Alcohol Drinks of the World

Product	*Substrate*	*Sensory Property and Nature*	*Microorganisms*	*Country*	*References*
Soju	Rice, *nuruk*	Distilled liquor	Mold, yeasts	Korea	Steinkraus (1996)
Sura	Finger millet, *dheli*	Alcoholic, staple	Unknown	India	Thakur et al. (2004)
Takju	Rice or barley, wheat flour, sweet potato, starter (*nuruk)*	Lower or diluted concentration of *yakju* is known as *takju,* alcoholic beverage	*Sacch. cerevisiae, Hansenula anomala, Bacillus* sp., *Lactobacillus* sp.	Korea	Lee and Rhee (1970)
Tapai	Rice, cassava, *jui-paing*	Alcoholic beverage	Molds, yeasts	Malayasia	Wong and Jakson (1977)
Tapuy	Rice, bubod	Alcoholic beverage	*Saccharomycopsis fibuligera, Rhodotorula glutinis, Debaromyces hansenii, Candida parapsilosis, Trichosporon fennicum, Leuconostoc*	Philippines	Tanimura et al. (1977)
Tchoukoutou	Red sorghum	Effervescent, sweet, beer	*Sacch. cerevisiae, Hanseniaspora uvarum, H. guillermondii, Kl. marxianus, Clavispora lusitaniae*	Benin	Greppi et al. (2013a,b)
Tej	Honey	Sweet, effervescent, cloudy alcoholic	*Sacch. cerevisiae, Kluyvermyces bulgaricus, K. veronae, Debaromyces phaffi, Lactobacillus, Streptococcus, Leuconostoc, Pediococcus* spp.	Mexico	Bahiru et al. (2006)

Tequila	Agave juice	Effervescent, sweet, distilled alcoholic drink	LAB, *Sacch. cerevisiae, Candida lusitaniae, Kluyvermyces marxianus, Pichia fermentans*	Mexico	De León-Rodŕiguez et al. (2006)
Themsing	Finger millet, barley	Mild-alcoholic, sweet, alcoholic beverage	Molds, yeasts	India	Tamang (2010a)
Tien-chiu-niang	Rice, *chiu-yueh*	Mild-alcoholic, sweet, alcoholic beverage	Molds, yeasts	China, Taiwan	Tamang (2010c)
Tari or *Toddy*	Palmyra and date palm sap	Sweet, milky, effervescent and mild alcoholic, alcoholic beverage	*Sacch. cerevisiae, Schizosaccharomyces pombe, Acetobacter aceti, A. rancens, A. suboxydans, Leuc. dextranicum, Micrococcus* sp., *Pediococcus* sp., *Bacillus* sp., *Sarcina* sp.	India	Shamala and Sreekantiah (1988)
Togwa	Maize	Cooked slurry, alcoholic beverage	Yeasts, LAB	East Africa	Tamang (2010c)
Yakju	Rice, wheat, barley, maize, *nuruk*	Alcoholic beverage	*Sacch. cerevisae, Hansenula* spp.	Korea	Kim and Kim (1993)
Yu	Rice, *hamei*	Distilled from *atingba*, alcoholic drink	Yeasts, LAB	India	Singh and. Singh (2006)
Zu	Rice	Distilled from fermented rice; clear liquor	Yeasts, LAB	India	Tamang (2010a)
Zutho/Zhuchu	Rice, *khekhrii*	Milky white, sweet-sour, mild-alcoholic	*Sacch. cerevisiae*	India	Tamang et al. (2012)

starter in preparation of *koji* for production of *saké, shoyu, miso, shochu* (Lee et al. 2007, Suganuma et al. 2007). The predominant fungi in Chinese *koji* are *Aspergillus* and *Candida* species along with a few species of bacteria *Weissella* and *Staphylococcus* (Yan et al. 2013).

1.6.2 Alcoholic Beverages and Drinks

There are 10 major categories of alcoholic beverages consumed/drunk across the world (Tamang 2010c, Table 1.12):

1. Nondistilled and unfiltered alcoholic beverages produced by amylolytic starters
2. Nondistilled and filtered alcoholic beverages produced by amylolytic starters
3. Distilled alcoholic beverages produced by amylolytic starters
4. Alcoholic beverages produced by human saliva
5. Alcoholic beverages produced by mono-fermentation
6. Alcoholic beverages produced from honey
7. Alcoholic beverages produced from plants
8. Alcoholic beverages produced by malting (germination)
9. Alcoholic beverages prepared from fruits without distillation
10. Distilled alcoholic beverages prepared from fruits and cereals

1.6.3 Nondistilled and Unfiltered Alcoholic Beverages Produced by Amylolytic Starters

Common examples of nondistilled and unfiltered alcoholic beverages produced by mixed amylolytic starters are *lao-chao* of China, *tapé* of Indonesia, *makgeolli* of Korea, *bhaati jaanr* and *kodo ko jaanr* of India and Nepal (Tamang 2010c), *kanji* of India (Tamang 2012b). The biological process of liquefaction and saccharification of cereal starch by filamentous molds and yeasts, supplemented by amylolytic starters, under solid-state fermentation is one of the two major stages of production of alcoholic beverages in Asia. These alcoholic beverages are mostly considered as food beverages and eaten as a staple food with high calories in many parts of Asia, for example, *kodo ko jaanr*, a fermented finger millet beverage of the Himalayan regions in India, Nepal, Bhutan, and China (Tibet) with 5% alcohol content (Thapa and Tamang 2004). *Marcha* used as an amylolytic starter supplements functional microorganisms in *kodo ko jaanr* fermentation. Yeasts *Candida glabrata, Pic. anomala, Sacch. cerevisiae, Sm. fibuligera*, and LAB *Lb. bifermentans* and *Ped. pentosaceus* have been recovered in *kodo ko jaanr* samples (Thapa and Tamang 2004). Saccharifying activities are mostly shown by *Rhizopus* spp. and *Sm. fibuligera* whereas liquefying activities are shown by *Sm. fibuligera* and *Sac. cerevisiae* (Thapa and Tamang 2006). *Bhaati jaanr* is the Himalayan sweet-sour, mild alcoholic food beverage paste prepared from rice and consumed as a staple food (Tamang and Thapa 2006). *Rhizopus, Amylomyces, Torulopsis*, and *Hansenula* are present in *lao-chao*, a popular ethnic fermented rice beverage of China (Wei and Jong 1983). During fermentation of *makgeolli* (a traditional Korean alcoholic beverage prepared by the amylolytic starter *nuruk*) the proportion of family Saccharomycetaceae increased significantly, and the major bacterial phylum of the samples shifted from γ-*Proteobacteria* to *Firmicutes* (Jung et al. 2012).

Kanji is an ethnic Indian strong-flavored but mild alcoholic beverage prepared from beet and carrots by natural fermentation (Batra and Millner 1974). It is drunk as a mild-alcoholic refreshing drink in India. Alcohol content in *kanji* is 2.5% and pH is 4.0 showing the product as mild-alcoholic and acidic in taste (Sura et al. 2001). During its preparation, carrots or beet are washed, shredded and mixed with salt and mustard seeds and placed in earthen pot and allowed to ferment naturally at 26–34°C for 4–7 days. Sometimes, the mixture is inoculated with a portion of a previous batch of *kanji*. After fermentation, a pink alcoholic liquor is drained off and bottled or drunk directly. In north India it is prepared with purple or occasionally orange cultivars of carrots plus beet and spices, whereas in south India *torami*, yeast-containing fermented rice gruel is used as a starter for *kanji* production. *Hansenlu anomala, Candida guilliermondii, C. tropicalis,* and *Geotrichium candidum* are involved in *kanji* fermentation (Batra and Millner 1974). *Leuc. mesenteroides, Pediococcus* spp. and *Lb. dextranicum* were isolated from *kanji* fermentation (Sura et al. 2001). Kingston et al. (2010) reported *Lb. paraplantarum* and *Lb. pentosus* from *kanji* based on rep-PCR identification method.

1.6.4 Nondistilled and Filtered Alcoholic Beverages Produced by Amylolytic Starters

Nondistilled and filtered alcoholic beverages produced by amylolytic starters are *saké* of Japan, *krachae* or *nam-khaao* or *sato* of Thailand, *basi* of the Philippines, *yakju* and *takju* of Korea (Table 1.12). Alcoholic beverages produced by an amylolytic starter (*koji*) is not distilled but the extract of the fermented cereals is filtered into clarified high alcohol-content liquor, for example, *saké* which is the national drink of Japan and is one of the most popular traditional nondistilled alcoholic drinks in the world. It is prepared from rice using *koji* and is clear, pale yellow, containing 15%–20% alcohol (Tamang 2010c). Improved strains of *Asp. oryzae* are used for *saké* production on an industrial scale (Kotaka et al. 2008, Hirasawa et al. 2009).

1.6.5 Distilled Alcoholic Beverages Produced by Amylolytic Starters

This category of alcoholic drinks are the clear, distillate part of high alcohol-content drinks prepared from fermented cereal beverages by using amylolytic starters, for example, *raksi* of India, Nepal, and Bhutan, *shochu* of Japan, *soju* of Korea. *Raksi* is an ethnic alcoholic (22%–27% v/v) drink of the Himalayas with a characteristic aroma, and distilled from traditional fermented cereal beverages (Kozaki et al. 2000).

1.6.6 Alcoholic Beverages Produced by Human Saliva

Traditionally, saliva serves as the source of amylase for conversion of cereal starch to fermentation sugars. *Chicha* is a unique ethnic fermented alcoholic (2%–12% v/v) beverage of the Andes Indians of South America, mostly Peru, and is prepared from maize by the human salivation process (Escobar et al. 1996, Hayashida 2008). *Sacch. cerevisiae, Sacch. apiculata, Sacch. pastorianus*, and species of *Lactobacillus* and *Acetobacter* are present in *chicha* (Escobar 1977). *Sacch. cerevisiae* was isolated from *chicha* and identified using MALDI-TOF (Vallejo et al. 2013).

1.6.7 Alcoholic Beverages Produced by Mono Fermentation

Beer, a fermented extract of malted barley with alcohol content of 2%–8%, is the most common example of mono fermentation (*Sacch. cerevisiae* strain). Strains within *Sacch. carlsbergensis* and *Sacch. uvarum* have been merged into either *Sacch. cerevisiae* or *Sacch. pastorianus* (Kurtzman and Robnet 2003). Species of *Dekkera* produce high levels of acetic acid and esters, *Pichia* and *Hansenula* species give excessive ester production in beer (Dufour et al. 2003).

1.6.8 Alcoholic Beverage Produced from Honey

Some alcoholic beverages are produced from honey, for example, *tej* of Ethiopia. It is a yellow, sweet, effervescent and cloudy alcoholic (7%–14% v/v) beverage (Steinkraus 1996). *Sacch. cerevisiae, Kluyvermyces bulgaricus, Debaromyces phaffi*, and *K. veronae*, and LAB *Lactobacillus, Streptococcus, Leuconostoc*, and *Pediococcus* species were isolated from *tej* fermentation (Bahiru et al. 2006).

1.6.9 Alcoholic Beverages Produced from Plants

Pulque is one of the oldest alcoholic beverages prepared from the juice of the cactus (*Agave*) plant of Mexico (Steinkraus 1996). Bacteria present during the fermentation of *pulque* were LAB—*Lc. lactis* subsp. *lactis, Lb. acetotolerans, Lb. acidophilus, Lb. hilgardii, Lb. kefir, Lb. plantarum, Leuc. citreum, Leuc. kimchi, Leuc. mesenteroides, Leuc. pseudomesenteroides,* the γ-Proteobacteria—*Erwinia rhapontici, Enterobacter* spp. and *Acinetobacter radioresistens,* several α-Proteobacteria—*Zymomonas mobilis, Acetobacter malorum, Acetobacter pomorium, Microbacterium arborescens, Flavobacterium johnsoniae, Gluconobacter oxydans*, and *Hafnia alvei* (Escalante et al. 2004, 2008). Yeasts isolated from *pulque* include *Saccharomyces* (*Sacch. bayanus, Sacch. cerevisiae, Sacch. paradoxus*) and non-*Saccharomyces* (*Candida* spp., *C. parapsilosis, Clavispora lusitaniae, Hanseniaspora uvarum, Kl. lactis, Kl. marxianus, Pichia membranifaciens, Pichia* spp., *Torulaspora delbrueckii*) (Lappe-Oliveras et al. 2008).

Toddy or *tari* is an ethnic alcoholic drink of India prepared from palm juice. There are three types of *toddy* (Batra and Millner 1974): (1) *sendi,* from the palm; (2) *tari,* from the *palmyra* and date palms; and (3) *nareli*, from the coconut palm. *Geotrichum, Saccharomyces* and *Schizosacchoramyces* spp. of yeast are responsible for fermentation (Batra and Millner 1974, 1976). Microorganisms that are responsible in fermenting *toddy* are *Sacch. cerevisiae, Schizosaccharomyces pombe, Acetobacter aceti, A. rancens, A. suboxydans, Leuc. dextranicum, Micrococcus* sp., *Pediococcus* sp., *Bacillus* sp., and *Sarcina* sp. (Shamala and Sreekantiah 1988).

1.6.10 Alcoholic Beverages Produced by Malting or Germination

Malting or germination process allows amylase to break down cereal starch to sugars, which are used as substrates for alcohol fermentation, for example, *Bantu* beer or sorghum beer of the Bantu tribes of South Africa (Taylor 2003). The major part of the sorghum crop (*Sorghum caffrorum* or *S. vulgare*) is malted and used for brewing beer (Kutyauripo et al. 2009).

1.6.11 Alcoholic Beverages Produced from Fruits without Distillation

Wine generally refers to the alcoholic fermentation of grape juice, or other fruits, without distillation. Until 75–100 years ago, most wines were produced by spontaneous or natural alcoholic fermentation of grape juice by indigenous yeast flora (Walker 2014). Wine fermentation is initiated by the growth of various species of *Saccharomyces* and non-*Saccharomyces* yeasts (e.g., *Candida colliculosa, C. stellata, Hanseniaspora uvarum, Kloeckera apiculata, Kl. thermotolerans, Torulaspora delbrueckii*, *Metschnikowia pulcherrima*) (Versavaud et al. 1995, Pretorius 2000, Moreira et al. 2005, Sun et al. 2014). Using mCOLD-PCR-DGGE method, *Candida* sp. and *Cladosporium* sp. were isolated from fermenting white wine, which were not detected by conventional PCR (Takahashi et al. 2014). *Sacch. cerevisiae* strains develop during wine fermentation which play an active role in the characteristics of wine (Vilanova and Sieiro 2006, Capece et al. 2013).

1.6.12 Distilled Alcoholic Beverages without Amylolytic Starters

Distillate high alcohol-content spirit from fermented cereal is whisky, fermented molasses is rum and fermented grape is brandy. Rum production from molasses fermentation may involve contributions from *Schizosaccharomyces pombe* and *Sacch. cerevisiae* (Fahrasame and Ganow-Parfeit 1998).

1.6.13 Recommendations

- Exchange of LAB strains/cultures from plant-origins with superior functional properties to ferment new animal products (milks, meat, sausages, etc.).
- Every country to establish microbial sequence banks and culture collection centres, of strains/cultures isolated from naturally fermented foods and beverages.
- Basic training on molecular microbial taxonomy and identification.
- Incorporation of published research materials on ethnic fermented foods and beverages into academic programs at master and doctoral level in Food Microbiology/Biotechnology/Food Science and Technology courses in universities following the references of the academic program on fermented foods in Sikkim University (India) and Wageningen University (the Netherlands).

1.7 Conclusion

The sustainable use of microorganisms in food fermentation is based on the interrelationship of indigenous knowledge of food fermentation, modern expertise and information, basic understanding of the microbial background of fermentation and of Good Hygienic Practices (GHP), some experience in handling of microbial strains or cultures, even under crude conditions such as back-slopping, and conservation of microbial strains. The diversity of functional microorganisms in fermented foods and beverages consists of bacteria, yeasts, and fungi. Microorganisms establish on relevant substrates for survival and produce bioactive compounds that enrich the human diet, thereby benefiting the health of consumers. Ethnic fermented foods of the world are considered to be a means to preserve microbial diversity *ex situ* and they are custodians of microbial diversity and play a key role in the storage and supply of authentic reference material for research and development. One of the challenges facing scientists in the future will undoubtedly be to allow the large-scale production of fermented foods without losing the unique flavor and other traits associated with the traditional products from which they are derived.

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