frontiers in Microbiology

REVIEW
published: 24 March 2016
doi: 10.3389/fmicb.2016.00377

CrossMark

Review: Diversity of Microorganisms in Global Fermented Foods and Beverages

Jyoti P. Tamang[1]*, *Koichi Watanabe*[2] *and Wilhelm H. Holzapfel*[3]

[1] Department of Microbiology, School of Life Sciences, Sikkim University, Tadong, India, [2] Department of Animal Science and Technology, National Taiwan University, Taipei, Taiwan, [3] Advance Green Energy and Environment Institute, Handong Global University, Pohang-si, South Korea

Culturalable and non-culturable microorganisms naturally ferment majority of global fermented foods and beverages. Traditional food fermentation represents an extremely valuable cultural heritage in most regions, and harbors a huge genetic potential of valuable but hitherto undiscovered strains. Holistic approaches for identification and complete profiling of both culturalable and non-culturable microorganisms in global fermented foods are of interest to food microbiologists. The application of culture-independent technique has thrown new light on the diversity of a number of hitherto unknown and non-cultural microorganisms in naturally fermented foods. Functional bacterial groups ("phylotypes") may be reflected by their mRNA expression in a particular substrate and not by mere DNA-level detection. An attempt has been made to review the microbiology of some fermented foods and alcoholic beverages of the world.

Keywords: global fermented foods, LAB, *Bacillus*, yeasts, filamentous molds

OPEN ACCESS

Edited by:
Abd El-Latif Hesham,
Assiut University, Egypt

Reviewed by:
Catarina Prista,
Instituto Superior de Agronomia, Portugal
Chiara Montanari,
Centro Interdipartimentale di Ricerca Industriale Agroalimentare, Italy

***Correspondence:**
Jyoti P. Tamang
jyoti_tamang@hotmail.com

Specialty section:
This article was submitted to Food Microbiology, a section of the journal Frontiers in Microbiology

Received: 14 December 2015
Accepted: 08 March 2016
Published: 24 March 2016

Citation:
Tamang JP, Watanabe K and Holzapfel WH (2016) Review: Diversity of Microorganisms in Global Fermented Foods and Beverages. Front. Microbiol. 7:377. doi: 10.3389/fmicb.2016.00377

INTRODUCTION

Traditionally, boiled rice is a staple diet with fermented and non-fermented legume (mostly soybeans) products, vegetables, pickles, fish, and meat in Far-East Asia, South Asia, North Asia, and the Indian subcontinent excluding Western and Northern India; while wheat/barley-based breads/loaves comprise a staple diet followed by milk and fermented milk products, meat, and fermented meats (sausages) in the Western and Northern part of India, West Asian continent, Europe, North America, and even in Australia and New Zealand (Tamang and Samuel, 2010). Sorghum/maize porridges, on the other hand, are the main courses of diet with many fermented and non-fermented sorghum/maize/millets, cassava, wild legume seeds, meat, and milk products in Africa and South America. Fermented foods are the hub of consortia of microorganisms, since they are either present as natural indigenous microbiota in uncooked plant or animal substrates, utensils, containers, earthen pots, and the environment (Hesseltine, 1979; Franz et al., 2014), or add starter culture(s) containing functional microorganisms (Holzapfel, 1997; Stevens and Nabors, 2009) which modify the substrates biochemically, and organoleptically into edible products that are culturally and socially acceptable to the consumers (Campbell-Platt, 1994; Steinkraus, 1997; Tamang, 2010b). Microorganisms convert the chemical composition of raw materials during fermentation, which enrich the nutritional value in some fermented foods, and impart health-benefits to the consumers (Steinkraus, 2002; Farhad et al., 2010; Tamang, 2015a).

Several researchers have reviewed the microbiology, biochemistry, and nutrition of fermented foods and beverages from different countries of Asia (Hesseltine, 1983; Steinkraus, 1994, 1996; Nout and Aidoo, 2002; Tamang et al., 2015); Africa (Odunfa and Oyewole, 1997; Olasupo et al., 2010; Franz et al., 2014); Europe (Pederson, 1979; Campbell-Platt, 1987; Wood, 1998); South America (Chaves-López et al., 2014), and North America (Doyle and Beuchat, 2013). Many genera/species of microorganisms have been reported in relation to various fermented foods and beverages across the world; the usage of molecular tools in recent years have helped to clarify, at least in part, the nomenclatural confusion and generalization caused by conventional (phenotypic) taxonomic methods. The present paper is an attempt to collate and review the updated information on microbiology of some globally fermented foods and beverages.

Microorganisms in Fermented Foods

Lactic acid bacteria (LAB) are widely present in many fermented foods and beverages (Stiles and Holzapfel, 1997; Tamang, 2010b). Major genera of the LAB such as *Alkalibacterium*, *Carnobacterium, Enterococcus*, *Lactobacillus*, *Lactococcus*, *Leuconostoc*, *Oenococcus*, *Pediococcus*, *Streptococcus*, *Tetragenococcus*, *Vagococcus,* and *Weissella* (Salminen et al., 2004; Axelsson et al., 2012; Holzapfel and Wood, 2014) have been isolated from various globally fermented foods and beverages.

Bacillus is present in alkaline-fermented foods of Asia and Africa (Parkouda et al., 2009; Tamang, 2015b). Species of *Bacillus* that are present, mostly in legume-based fermented foods, are *Bacillus amyloliquefaciens, Bacillus circulans, Bacillus coagulans, Bacillus firmus*, *Bacillus licheniformis, Bacillus megaterium, Bacillus pumilus, Bacillus subtilis, Bacillus subtilis* variety *natto,* and *Bacillus thuringiensis* (Kiers et al., 2000; Kubo et al., 2011), while strains of *Bacillus 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 of a sticky texture to the product (Urushibata et al., 2002; Nishito et al., 2010).

The association of several species of *Kocuria, Micrococcus* (members of the *Actinobacteria*), and *Staphylococcus* (belonging to the *Firmicutes*) has been reported for fermented milk products, fermented sausages, meat, and fish products (Martín et al., 2006; Coton et al., 2010). Species of *Bifidobacterium, Brachybacterium, Brevibacterium,* and *Propionibacterium* are isolated from cheese, and species of *Arthrobacter* and *Hafnia* from fermented meat products (Bourdichon et al., 2012). *Enterobacter cloacae*, *Klebsiella pneumoniae, K. pneumoniae* subsp. *ozaenae, Haloanaerobium, Halobacterium, Halococcus*, *Propionibacterium, Pseudomonas,* etc. are also present in many global fermented foods (Tamang, 2010b).

Genera of yeasts reported for fermented foods, alcoholic beverages and non-food mixed amylolytic starters are mostly *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; Lv et al., 2013).

Major role of filamentous molds in fermented foods and alcoholic beverages is the production of enzymes and the degradation of anti-nutritive factors (Aidoo and Nout, 2010). Species of *Actinomucor, Amylomyces, Aspergillus, Monascus, Mucor, Neurospora, Parcilomyces, Penicillium, Rhizopus,* and *Ustilago* are reported for many fermented foods, Asian non-food amylolytic starters and alcoholic beverages (Nout and Aidoo, 2002; Chen et al., 2014).

TAXONOMIC TOOLS FOR IDENTIFICATION OF MICROORGANISMS FROM FERMENTED FOODS

Use of culture media may ignore several unknown non-culturable microorganisms that may play major or minor functional roles in production of fermented foods. Direct DNA extraction from samples of fermented foods, commonly known as culture-independent methods, is nowadays frequently used in food microbiology to profile both culturable and non-culturable microbial populations from fermented foods (Cocolin and Ercolini, 2008; Alegría et al., 2011; Cocolin et al., 2013; Dolci et al., 2015), provided that the amplification efficiency is high enough. PCR-DGGE analysis is the most popular culture-independent technique used for detecting microorganisms in fermented foods and thereby profiling both bacterial populations (Cocolin et al., 2011; Tamang, 2014) and yeast populations in fermented foods (Cocolin et al., 2002; Jianzhonga et al., 2009). Both culturable and non-culturable microorganisms from any fermented food and beverage may be identified using culture-dependent and -independent methods to document a complete profile of microorganisms, and also to study both inter- and intra-species diversity within a particular genus or among genera (Ramos et al., 2010; Greppi et al., 2013a,b; Yan et al., 2013). A combination of Propidium MonoAzide (PMA) treatment on samples before DNA extraction and molecular quantifying method can be used to accurately enumerate the viable microorganisms in fermented foods (Desfossés-Foucault et al., 2012; Fujimoto and Watanabe, 2013).

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 (Giraffa and Carminati, 2008; Dolci et al., 2015). Species-specific PCR primers are used for species level identification (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 enables the specific detection and quantification of LAB species in fermented foods (Park et al., 2009).

Random amplification of polymorphic DNA (RAPD) is a typing method based on the genomic DNA fragment profiles amplified by PCR, and is commonly used for disintegration of LAB strains from fermented foods (Coppola et al., 2006; Chao et al., 2008). The repetitive extragenic palindromic sequence-based PCR (rep-PCR) technique permits typing at subspecies level and reveals significant genotypic differences among strains of the same bacterial species from fermented food samples (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 in identification and to discriminate has been demonstrated for various LAB strains (Tanigawa and Watanabe, 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 and 26S rDNA amplicons produced by PCR (Ercolini, 2004; Flórez and Mayo, 2006; Alegría et al., 2011). However, DGGE has some disadvantages as well like it is time consuming, unable to determine the relative abundance of dominant species and distinguish between viable and nonviable cells, as well as it has difficulties in interpretation of multi-bands (Dolci et al., 2015). DGGE is also limited to detect specific species as it may only reveal some of the major bacterial species such as *B. licheniformis* and *Bacillus thermoamylovorans* in *chungkokjang* (sticky fermented soybean food of Korea) and not detect a large number of predominant or diverse rare bacterial species identified in pyrosequencing analysis (Nam et al., 2011).

The amplified ribosomal DNA restriction analysis (ARDRA) technique using restriction enzymes is also useful in identification of microorganisms from fermented foods (Jeyaram et al., 2010).

Multilocus sequence analysis (MLSA), using housekeeping genes as molecular markers alternative to the 16S rRNA genes, is used for LAB species identification: *rpoA* and *pheS* genes for *Enterococcus* and *Lactobacillus*, *atpA* and *pepN* for *Lactococcus* species, and *dnaA*, *gyrB*, and *rpoC* for species of *Leuconostoc, Oenococcus*, and *Weissella* (de Bruyne et al., 2007, 2008b, 2010; Diancourt et al., 2007; Picozzi et al., 2010; Tanigawa and Watanabe, 2011).

Effective tools of next generation sequencing (NGS) such as metagenomics, phylobiomics, and metatranscriptomics are nowadays applied for documentation of cultures in traditionally fermented products (Mozzi et al., 2013; van Hijum et al., 2013). However, NGS as a sophisticated tool needs well-trained hands and a well-equipped molecular laboratory, which may not always be available. Application of metagenomic approaches, by using parallel pyrosequencing of tagged 16S rRNA gene amplicons, provide information on microbial communities as profiled in *kimchi*, a naturally fermented vegetable product of Korea (Jung et al., 2011; Park et al., 2012), *nukadoko*, a fermented rice bran of Japan (Sakamoto et al., 2011), *narezushi*, a fermented salted fish and cooked rice of Japan (Kiyohara et al., 2012), and *ben-saalga*, a traditional gruel of pearl millet of Burkina Faso (Humblot and Guyot, 2009). Pyrosequencing has revealed the presence of numerous and even minor bacterial groups in fermented foods, but DNA-level detection does not distinguish between metabolically "active" and "passive" organisms. "Functionally relevant phylotypes" in an ecosystem may be specifically detected by, e.g., weighted UniFrac principal coordinate analysis based on 454 pyrosequencing of 16S rRNA genes, as applied in studies on gut microbiota (Wang et al., 2015). The 16S rRNA gene sequence based pyrosequencing method enables a comprehensive and high-throughput analysis of microbial ecology (Sakamoto et al., 2011), and this method has been applied to various traditionally fermented foods (Oki et al., 2014).

A proteomics identification method based on protein profiling using matrix-assisted laser desorption ionizing-time of flight mass spectrometry (MALDI-TOF MS) has been used to identify species of *Bacillus* in fermented foods of Africa (Savadogo et al., 2011), and species of LAB isolated from global fermented foods (Tanigawa et al., 2010; Dušková et al., 2012; Sato et al., 2012; Nguyen et al., 2013a; Kuda et al., 2014).

Global Fermented Foods

Campbell-Platt (1987) reported around 3500 global fermented foods and beverages, and had divided them into about 250 groups. There might be more than 5000 varieties of common and uncommon fermented foods and alcoholic beverages being consumed in the world today by billions of people, as staple and other food components (Tamang, 2010b). Global fermented foods are classified into nine major groups on the basis of substrates (raw materials) used from plant/animal sources: (1) fermented cereals, (2) fermented vegetables and bamboo shoots, (3) fermented legumes, (4) fermented roots/tubers, (5) fermented milk products, (6) fermented and preserved meat products, (7) fermented, dried and smoked fish products, (8) miscellaneous fermented products, and (9) alcoholic beverages (Steinkraus, 1997; Tamang, 2010b,c).

Fermented Milk Products

Fermented milk products (**Table 1**) are classified into two major groups on the basis of microorganisms: (A) lactic fermentation, dominated by species of LAB, comprising the "thermophilic" type (e.g., yogurt, Bulgarian buttermilk), probiotic type (e.g., acidophilus milk, bifidus milk), and the mesophilic type (e.g., natural fermented milk, cultured milk, cultured cream, cultured buttermilk); and (B) fungal-lactic fermentations, where LAB and yeasts cooperate to generate the final product, which include alcoholic milks (e.g., acidophilus-yeast milk, *kefir, koumiss*), and moldy milks (e.g., *viili*; Mayo et al., 2010). Natural fermentation is one of the oldest methods of milk processing using raw and boiled milk to ferment spontaneously, or of using the back-slopping method where a part of the previous batch of a fermented product is used to inoculate the new batch (Holzapfel, 2002; Josephsen and Jespersen, 2004). Cheese and cheese products derived from the fermentation of milk are of major nutritional and commercial importance throughout the world (de Ramesh et al., 2006). Starter cultures in milk fermentation are of two types: primary cultures that are mostly *Lactococcus lactis* subsp. *cremoris, Lc. lactis* subsp. *lactis, Lactobacillus delbrueckii* subsp. *delbrueckii*, *Lb. delbrueckii* subsp. *lactis, Lb. helveticus, Leuconostoc* spp., and *Streptococcus thermophilus* to participate

TABLE 1 | Microorganisms isolated from some common and uncommon fermented milk products of the world.

Product	Substrate	Sensory property and nature	Microorganisms	Country	References
Airag	Mare or camel milk	Acidic, sour, mild alcoholic drink	*Lb. helveticus, Lb. kefiranofaciens, Bifidobacterium mongoliense*, *Kluyveromyces marxianus*	Mongolia	Watanabe et al., 2008, 2009b; Yu et al., 2011
Amasi	Cow milk	Acidic, sour, with thick consistency	*Lc. lactis* subsp. *lactis* (dominating), *Lc. lactis* subsp. *cremoris, Lactobacillus, Enterococcus,* and *Leuconostoc* spp. Several non-culturable strains	South Africa, Zimbabwe	Osvik et al., 2013
Cheese	Animal milk	Soft or hard, solid; side dish, salad, used in many cooked/baked dishes	*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, Candida* sp. *Saccharomycopsis* sp.	India, Nepal, Bhutan, China (Tibet)	Dewan and Tamang, 2006
Chhurpi	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. confusa, 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. cibaria, 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
Dadih	Buffalo milk	Curd, savory	*Leuc. mesenteroides*, *Ent. faecalis*, *Strep. lactis* supsp. *lactis*, *Strep. cremoris*, *Lb. casei* subsp. *casei,* and *Lb. casei* subsp. *rhamnosus*	Indonesia	Hosono et al., 1989
Kefir	Goat, sheep, cow	Alcoholic fermented milk, effervescent milk	*Lb. brevis, Lb. caucasicus, Strep. thermophilus, Lb. bulgaricus, Lb. plantarum, Lb. casei, Lb. brevis, Tor. holmii, Tor. delbruechii*	Russia	Bernardeau et al., 2006
Koumiss	Milk	Acid fermented milk, drink	*Lb. bulgaricus, Lb. salivarius, Lb. buchneri, Lb. heveticus, Lb. plantarum, Lb. acidophilus, Torula* sp.	Russia, Mongolia	Wu et al., 2009; Hao et al., 2010
Laban rayeb	Milk	Acid fermented milk, yogurt-like	*Lb. casei, Lb. plantarum, Lb. brevis, Lact. lactis, Leuconostoc* sp., *Sacch. kefir*	Egypt	Bernardeau et al., 2006
Leben / Lben	Cow milk	Sour milk	*Candida* sp., *Saccharomyces* sp., *Lactobacillus* sp., *Leuconostoc* sp.	North, East Central Africa	Odunfa and Oyewole, 1997
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)

TABLE 1 | Continued

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 confusa, Candida parapsilosis, C. rugosa, C. tropicalis, Galactomyces geotrichum, Pichia kudriavzevii*, *Sacch. cerevisiae*	Ghana	Akabanda et al., 2013
Philu	Cow/ yak milk	Cream like product, curry	*Lb. paracasei, Lb. bifermentans, Ent. faecium*	India, Nepal, Tibet (China)	Dewan and Tamang, 2007
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	Sarkar, 2008; Singh and Singh, 2014
Somar	Yak or cow milk	Buttermilk	*Lb. paracasei, Lact. lactis*	India, Nepal	Dewan and Tamang, 2007
Sua chua	Dried skim milk, starter, sugar	Acid fermented milk	*Lb. bulgaricus, Strep. thermophilus*	Vietnam	Alexandraki et al., 2013
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
Yogurt	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; Angelakis et al., 2011

in the acidification (Parente and Cogan, 2004); and secondary cultures that are used in cheese-making are *Brevibacterium linens, Propionibacterium freudenreichii, Debaryomyces hansenii, Geotrichum candidum, Penicillium camemberti,* and *P. roqueforti* for development of flavor and texture during ripening of cheese (Coppola et al., 2006; Quigley et al., 2011). Some non-starter lactic acid bacteria (NSLAB) microbiota are usually present in high numbers in fermented milk, which include *Enterococcus durans, Ent. faecium, Lb. casei, Lb. plantarum, Lb. salivarius,* and *Staphylococcus* spp. (Briggiler-Marcó et al., 2007).

Fermented Cereal Foods

In most of the Asian countries, rice is fermented either by using mixed-culture(s) into alcoholic beverages or by using food beverages (Tamang, 2010c), whereas in Europe, America, and Australia, most cereals like wheat, rye, barley and maize are fermented by natural fermentation or by adding commercial baker's yeast into the batter for dough breads/loaves (Guyot, 2010). In Africa, fermented cereal foods are traditionally used as staples as well as complementary and weaning foods for infants and young children (Tou et al., 2007). In Europe, people still practice the old traditional method of preparation of breads or loaves without using any commercial strains of baker's yeast (Hammes and Ganzle, 1998). Yeasts and LAB conduct dough fermentation, mostly San Francisco sourdough, and the resultant products are generally called sourdough breads because they have higher contents of lactic acid and acetic acid due to the bacterial growth (Brandt, 2007; de Vuyst et al., 2009).

Cereal fermentation is mainly represented by species of LAB and yeasts (Corsetti and Settanni, 2007). *Enterococcus*, *Lactococcus*, *Lactobacillus*, *Leuconostoc*, *Pediococcus*, *Streptococcus,* and *Weissella* are common bacteria associated with cereal fermentations (**Table 2**; de Vuyst et al., 2009; Guyot, 2010; Moroni et al., 2011). Native strains of *Saccharomyces cerevisiae* are the principal yeast of most bread fermentations (Hammes et al., 2005), but other non-*Saccharomyces* yeasts are also significant in many cereal fermentations including *Candida, Debaryomyces, Hansenula, Kazachstania, Pichia, Trichosporon,* and *Yarrowia* (Iacumin et al., 2009; Weckx et al., 2010; Johnson and Echavarri-Erasun, 2011).

Fermented Vegetable Foods

Perishable and seasonal leafy vegetables, radish, cucumbers including young edible bamboo tender shoots are traditionally fermented into edible products (**Table 3**). Fermentation of vegetables is mostly dominated by species of *Lactobacillus* and *Pediococcus*, followed by *Leuconostoc, Weissella, Tetragenococcus*, and *Lactococcus* (Chang et al., 2008; Watanabe et al., 2009a). A complete microbial profile of LAB in *kimchi* has been characterized using different molecular identification tools (Shin

TABLE 2 | Microorganisms isolated from some common and uncommon fermented cereal foods of the world.

Product	Raw material/ Substrate	Sensory property and nature	Microorganisms	Country	References
Ang-kak	Red rice	Colorant	*Monascus purpureus*	China, Taiwan, Thailand, Philippines	Steinkraus, 1996
Boza	Cereals	Sour refreshing liquid	*Lactobacillus* sp., *Lactococcus* sp., *Pediococcus* sp., *Leuconostoc* sp., *Sacch. cerevisiae*	Bulgaria	Blandino et al., 2003
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
Ben-saalga	Pearl millet	Weaning food	*Lactobacillus* sp., *Pediococcus* sp., *Leuconostoc* sp., *Weissela* sp., yeasts	Burkina Faso, Ghana	Tou et al., 2007
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; Candidatropicalis, C. krusei, Kluyveromyces marxianus*	Benin	Vieira-Dalodé et al., 2007; Greppi et al., 2013a
Hussuwa	Sorghum	Cooked dough	*Lb. fermentum, Ped. acidilactici, Ped. pentosaceus*, Yeasts	Sudan	Yousif et al., 2010
Idli	Rice, black gram 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, doughnut-like, deep-fried, snacks	*Sacch. Bayanus, Lb. fermentum, Lb. buchneri, Lact. lactis, Ent. faecalis, Sacch. cerevisiae*	India, Nepal, Pakistan	Batra and Millner, 1976
Kenkey	Maize	Acidic, solid, steamed dumpling, staple	*Lb. plantarum, Lb. brevis, Ent. cloacae, Acinetobacter* sp., *Sacch. cerevisiae, Cand. mycoderma*	Ghana	Oguntoyinbo et al., 2011
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
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	Olasupo et al., 2010; Oguntoyinbo et al., 2011
Kisra	Sorghum	Thin pancake bread, staple	*Ped. pentosaceus, Lb. confusus, Lb. brevis, Erwinia ananas, Klebsiella pneumoniae, Ent. cloacae, Cand. intermedia, Deb. hansenii, Aspergillus* sp., *Penicillium* sp., *Fusarium* sp., *Rhizopus* sp.	Sudan	Hamad et al., 1997
Koko	Maize	Porridge	*Ent. clocae, Acinetobacter* sp., *Lb. plantarum, Lb. brevis, Sacch. cerevisiae, Cand. mycoderma*	Ghana	Blandino et al., 2003
Lao-chao	Rice	Paste, soft, juicy, glutinous dessert	*Rhiz. oryzae, Rhiz. chinensis, Chlamydomucor oryzae, Sacchromycopsis* sp.	China	Blandino et al., 2003

(Continued)

TABLE 2 | Continued

Product	Raw material/ Substrate	Sensory property and nature	Microorganisms	Country	References
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	Greppi et al., 2013a,b
Mbege	Maize, sorghum, millet	Submerged	*Sacch. cerevisiae*, *Schizosaccharomyces pombe*, *Lb. plantarum, Leuc. mesenteroides*	Tanzania	Odunfa and Oyewole, 1997
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	Greppi et al., 2013a
Pito	Maize, sorghum	Submerged	*Geotrichum candidum, Lactobacillus* sp., *Candida* sp.	West Africa	Odunfa and Oyewole, 1997
Poto poto	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	*Strep. bovis, Strep. macedonicus*, *Lc. lactis*, *Ent. sulfureus*	Mexico	Díaz-Ruiz et al., 2003
Puto	Rice	Steamed cake, breakfast	*Leuc. mesenteroides, Ent. faecalis, Ped. pentosaceus*, Yeasts	Philippines	Steinkraus, 2004
Rabadi	Buffalo or cow milk and cereals, pulses	Mild-acidic, thick slurry-like product	*Ped. acidilactici*, *Bacillus* sp., *Micrococcus* sp., yeasts	India, Pakistan	Gupta et al., 1992
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
Sourdough	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	Gänzle et al., 1998; de Vuyst et al., 2009
Tape Ketan	Glutinous rice, *Ragi*	Sweet, sour, mild alcoholic, dessert	*Thizopus* sp., *Chlamydomucor* sp., *Candida* sp., *Endomycopsis* sp., *Saccharomyces* sp.	Indonesia	Steinkraus, 1996
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	Sengun et al., 2009
Uji	Maize, sorghum, millet, cassava flour	Acidic, sour, porridge, staple	*Leuc. mesenteroides, Lb. plantarum*	Kenya, Uganda, Tanzania	Odunfa and Oyewole, 1997

et al., 2008; Nam et al., 2009; Park et al., 2010; Jung et al., 2011, 2013a). Natural fermentations during production of *sauerkraut*, a fermented cabbage product of Germany, had been studied and a species of LAB were reported. (Johanningsmeier et al., 2007; Plengvidhya et al., 2007). Species of LAB constitute the native population in the Himalayan fermented vegetable products such as *gundruk, sinki, goyang, khalpi,* and *inziangsang* (Karki et al., 1983; Tamang et al., 2005, 2009; Tamang and Tamang, 2007, 2010) and in several naturally fermented bamboo products of India and Nepal (Tamang and Sarkar, 1996; Tamang et al., 2008; Tamang and Tamang, 2009; Jeyaram et al., 2010; Sonar and Halami, 2014).

Fermented Soybeans and Other Legumes

Two types of fermented soybean foods are produced: soybean foods fermented by *Bacillus* spp. (mostly *B. subtilis*) with the stickiness characteristic, and soybean foods fermented by filamentous molds, mostly *Aspergillus, Mucor, Rhizopus* (Tamang, 2010b). *Bacillus*-fermented, non-salty and sticky soybean foods are concentrated in an imaginary triangle with three vertices lying each on Japan (*natto*), east Nepal and north-east India (*kinema* and its similar products), and northern Thailand (*thua-nao*), named as "*natto* triangle" (Nakao, 1972) and renamed as "*kinema-natto-thuanao* (KNT)-triangle"

TABLE 3 | Microorganisms isolated from some common and uncommon fermented vegetable products of the world.

Product	Substrate/ Raw materials	Sensory property and nature	Microorganisms	Country	References
Burong mustala	Mustard	Acidic, wet	*Lb. brevis, Ped. cerevisiae*	Philippines	Rhee et al., 2011
Cucumbers (fermented)	Cucumbers	Acidic, wet, pickle	*Leuc. mesenteroides*, *Ped. cerevisiae, Ped. acidilactici, Lb. plantarum, Lb. brevis*	Europe, USA, Canada	Pederson, 1979
Dha muoi	Mustard and beet, eggplant	Acidic, wet	*Lb. fermentum*, *Lb. pentosus, Lb. plantarum, Ped. pentosaceus, Lb. brevis, Lb. paracasei*, *Lb. pantheris, Ped. acidilactici*	Vietnam	Nguyen et al., 2013a
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
Goyang	Wild vegetable	Acidic, sour, wet, soup	*Lb. plantarum, L. brevis, Lc. 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, Lc. 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
Jiang-gua	Cucumber	Fermented cucumber, pickle	*Ent. casseliflavus, Leuc. lactis, Leuc. mesenteroides, Lb. pentosus, Lb. plantarum, Lb. paraplantarum, Lc. lactis* subsp. *lactis, W. cibaria, W. hellenica*	Taiwan	Chen et al., 2012
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
Kimchi	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. kimchii, W. cibaria, Lb. plantarum, Lb. sakei, Lb. delbrueckii, Lb. buchneri, Lb. brevis, Lb. fermentum, Ped. acidilactici, Ped. pentosaceus, Lc. Lactis,* yeasts species of *Candida, Halococcus, Haloterrigena, Kluyveromyces, Lodderomyces, Natrialba, Natronococcus, Pichia, Saccharomyces, Sporisorium* and *Trichosporon*	Korea	Chang et al., 2008; Nam et al., 2009; Jung et al., 2011
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 et al., 2008
Oiji	Cucumber, salt, water	Fermented cucumber	*Leuc. mesenteroides, Lb. brevis, Lb. plantarum, Ped. cerevisiae*	Korea	Alexandraki et al., 2013

(Continued)

TABLE 3 | Continued

Product	Substrate/ Raw materials	Sensory property and nature	Microorganisms	Country	References
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
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
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
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	Tamang et al., 2008; Jeyaram et al., 2010
Soidon	Bamboo shoot tips	Acidic, sour, soft, curry	*Lb. brevis, Lb. plantarum*, uncultured *Lb. acetotolera, Leuc. fallax, Leuc. citreumns*, *Lc. lactis* subsp. *cremoris*, *Weissella cibaria*, uncultured *W. ghanensis*	India	Tamang et al., 2008; Romi et al., 2015
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
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
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

(Tamang, 2015b). Within the KNT-triangle-bound countries, *Bacillus*-fermented sticky non-salty soybean foods are consumed such as *natto* of Japan, *chungkokjang* of Korea, *kinema* of India, Nepal and Bhutan, *aakhune, bekang*, *hawaijar*, *peruyaan*, and *tungrymbai* of India, *thua nao* of Thailand, *pepok* of Myanmar, and *sieng* of Cambodia and Laos (Nagai and Tamang, 2010; Tamang, 2015b; **Table 4**). Although, the method of production and culinary practices vary from product to product, plasmids, and phylogenetic analysis of *B. subtilis* showed the similarity among the strains of *B. subtilis* isolated from common sticky

TABLE 4 | Microorganisms isolated from some common and uncommon fermented legume (soybeans and non-soybean) products of the world.

Product	Substrate/Raw material	Sensory features and nature	Microorganisms	Country	References
Bekang	Soybean	Alkaline, sticky, paste, curry	*B. subtilis, B. brevis, B. circulans, B. coagulans, B. licheniformis, B. pumilus, B. sphaericus,* and *Lysinibacillus fusiformis*	India	Chettri and Tamang, 2015
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., 2008
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; Nam et al., 2012
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
Douchi	Soybean	Alkaline, paste	*B. amyloliquefaciens, B. subtilis, Asp. oryzae*	China, Taiwan	Wang et al., 2006; Zhang et al., 2007
Doenjang	Soybean	Alkaline, paste, soup	*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; Nam et al., 2011
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	Shin et al., 2012
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., 2008b; Singh et al., 2014
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	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
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

(Continued)

TABLE 4 | Continued

Product	Substrate/Raw material	Sensory features and nature	Microorganisms	Country	References
Kinema	Soybean	Alkaline, sticky; curry	*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
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, B. 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, Ped. halophilus, Streptococcus* sp., *Sacch. rouxii, Zygosaccharomyces rouxii, Asp. oryzae*	Japan	Asahara et al., 2006; Sugawara, 2010
Natto	Soybean	Alkaline, sticky, breakfast	*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	*Neurosporaintermedia, 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
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., 2004
Shoyu	Soybean	Alkaline, liquid, seasoning	*Asp. oryzae* or *Asp. sojae*, *Z. rouxii, C. versatilis*	Japan, Korea, China	Sugawara, 2010
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; Chao et al., 2008

(Continued)

TABLE 4 | Continued

Product	Substrate/Raw material	Sensory features and nature	Microorganisms	Country	References
Tauco	Soybean	Alkaline, paste, use as flavoring agent	*Rhiz. oryzae, Rhiz. ologosporus, Asp. oryzae, Zygosaccharomyces soyae, 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*	Indonesia	Winarno et al., 1973
Tempe	Soybean	Alkaline, solid, fried cake, breakfast	*Rhiz. oligisporus, Rhiz. arrhizus, Rhiz. oryzae, Rhiz. stolonifer, Asp. niger, 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	Feng et al., 2005; Jennessen et al., 2008
Thua nao	Soybean	Alkaline, paste, dry, side dish	*B. subtilis, B. pumilus, Lactobacillus* sp.	Thailand	Chunhachart et al., 2006
Tungrymbai	Soybean	Alkaline, sticky, curry, soup	*B. subtilis, B. licheniformis*, *B. pumilus*	India	Chettri and Tamang, 2015
Ugba	African oil bean (*Pentaclethra macrophylla*)	Alkaline, flat, glossy, brown in color	*B. subtilis, B. pumilus, B. licheniformis, Staph. saprophyticus*	Nigeria	Ahaotu et al., 2013
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
Yandou	Soybean	Alkaline, sticky, salted, snack	*B. subtilis*	China	Qin et al., 2013

fermented soybean foods of Asia (Hara et al., 1986, 1995; Tamang et al., 2002; Meerak et al., 2007) suggesting the common stock of *Bacillus*. Mould-fermented soybean products are *miso* and *shoyu* of Japan, *tempe* of Indonesia, *douchi* and *sufu* of China, and *doenjang* of Korea (Sugawara, 2010). Some common non-soybean fermented legumes (e.g., locust beans) are *bikalga, dawadawa, iru, okpehe, soumbala,* and *dugba* of Africa (Ouoba et al., 2004, 2008, 2010; Amoa-Awua et al., 2006; Azokpota et al., 2006; Oguntoyinbo et al., 2007, 2010; Meerak et al., 2008; Parkouda et al., 2009; Ahaotu et al., 2013), fermented black-grams products such as *dhokla, papad,* and *wari* of India (Nagai and Tamang, 2010), and *maseura* of India and Nepal (Chettri and Tamang, 2008).

Species of *Bacillus* have been reported for several Asian fermented soybean foods (Sarkar et al., 2002; Tamang et al., 2002; Tamang, 2003; Park et al., 2005; Inatsu et al., 2006; Choi et al., 2007; Kimura and Itoh, 2007; Shon et al., 2007; Jeyaram et al., 2008b; Dajanta et al., 2009; Kwon et al., 2009; Kubo et al., 2011; Singh et al., 2014; Wongputtisin et al., 2014; Chettri and Tamang, 2015). However, *B. subtilis* is the dominant functional bacterium in Asian fermented soybean foods (Sarkar and Tamang, 1994; Tamang and Nikkuni, 1996; Dajanta et al., 2011). Japanese *natto* is the only *Bacillus*-fermented soybean food now produced by commercial monoculture starter *B. natto*, earlier isolated from naturally fermented *natt*o by Sawamura (Sawamura, 1906). *Ent. Faecium*, as a minor population group, is also present in *kinema* (Sarkar et al., 1994), in *okpehe* (Oguntoyinbo et al., 2007), and in *chungkukjang* (Yoon et al., 2008).

Fermented Root and Tuber Products

Cassava (*Manihot esculenta*) root is traditionally fermented into staple foods such as *gari* in Nigeria; *fufu* in Togo, Burkina Faso, Benin and Nigeria; *agbelima* in Ghana; *chikawgue* in Zaire; *kivunde* in Tanzania; *kocho* in Ethiopia; and *foo foo* in Nigeria, Benin, Togo, and Ghana, respectively (Franz et al., 2014; **Table 5**). The initial stage of cassava fermentation is dominated by *Corynebacterium manihot* (Oyewole et al., 2004) with LAB succession (*Lb. acidophilus*, *Lb. casei, Lb. fermentum, Lb. pentosus, Lb. plantarum,* Oguntoyinbo and Dodd, 2010)**.** Cassava root is also traditionally fermented into sweet dessert known as *tapé* in Indonesia (Tamang, 2010b).

Fermented Meat Products

Fermented meat products are divided into two categories: those made from whole meat pieces or slices such as dried meat and jerky; and those made by chopping or comminuting the meat,

TABLE 5 | Microorganisms isolated from some 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
Fufu	Cassava	Submerged, staple	*Bacillus* sp., *Lb. plantarum, Leuc. mesenteroides, Lb. cellobiosus, Lb. brevis; Lb. coprophilus, Lc. lactis; Leuc. lactis, Lb. bulgaricus, Klebsiella* sp., *Leuconostoc* sp., *Corynebacterium* sp., *Candida* sp.	West Africa	Odunfa and Oyewole, 1997
Gari	Cassava	Solid state, staple	*Corynebacterium mannihot, Geotrichum* sp., *Lb. plantarium, Lb. buchnerri, Leuconsostoc* 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
Tapé	Cassava	Sweet dessert	*Streptococcus* sp., *Rhizopus* sp., *Saccharomycopsisfibuligera*	Indonesia	Suprianto Ohba 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

usually called sausages (Adams, 2010). Traditionally fermented meat products of many countries have been well-documented (**Table 6**), such as fermented sausages (Lücke, 2015) and *salami* (Toldra, 2007) of Europe, jerky of America and Africa (Baruzzi et al., 2006), *nham* of Thailand (Chokesajjawatee et al., 2009), and *nem chua* of Vietnam (Nguyen et al., 2013b). The main microbial groups involved in meat fermentation are LAB (Albano et al., 2009; Cocolin et al., 2011; Khanh et al., 2011; Nguyen et al., 2013b), followed by coagulase-negative staphylococci, micrococci and *Enterobacteriaceae* (Cocolin et al., 2011; Marty et al., 2011), and depending on the product, some species of yeasts (Encinas et al., 2000; Tamang and Fleet, 2009), and molds, which may play a role in meat ripening (Lücke, 2015).

Fermented Fish Products

Preservation of fish through fermentation, sun/smoke drying and salting (**Table 7**) is traditionally practiced by people living nearby coastal regions, lakes, and rivers and is consumed as seasoning, condiments, and side dishes (Salampessy et al., 2010). Several species of bacteria and yeasts have been reported from fermented and traditionally preserved fish products of the world (Kobayashi et al., 2000a,b,c; Wu et al., 2000; Thapa et al., 2004, 2006, 2007; Saithong et al., 2010; Hwanhlem et al., 2011; Romi et al., 2015).

Miscellaneous Fermented Products

Vinegar is one of the most popular condiments in the world and is prepared from sugar or ethanol containing substrates and hydrolyzed starchy materials by aerobic conversion to acetic acid (Solieri and Giudici, 2008). *Acetobacter aceti* subsp. *aceti, Acetobacter pasteurianus, Acetobacter polyxygenes, Acetobacter xylinum, Acetobacter malorum*, *Acetobacter pomorum* dominate during vinegar production (Haruta et al., 2006), while yeast species such as *Candida lactis-condensi*, *Candida stellata*, *Hanseniaspora valbyensis*, *Hanseniaspora osmophila*, *Saccharomycodes ludwigii, Sacch. cerevisiae, Zygosaccharomyces bailii, Zygosaccharomyces bisporus, Zygosaccharomyces lentus*, *Zygosaccharomyces mellis*, *Zygosaccharomyces Pseudorouxii,* and *Zygosaccharomyces Rouxii* have also been reported (Sengun and Karabiyikli, 2011).

Though normal black tea is consumed everywhere, some ethnic Asian communities enjoy special fermented teas such as *miang* of Thailand (Tanasupawat et al., 2007) and *puer* tea, *fuzhuan brick*, and *kombucha* of China (Mo et al., 2008). *Aspergillus niger* is the predominant fungus in *puer* tea while *Blastobotrys adeninivorans, Asp. glaucus*, species of *Penicillium*, *Rhizopus,* and *Saccharomyces* and the bacterial species *Actinoplanes* and *Streptomyces* are isolated (Jeng et al., 2007; Abe et al., 2008). *Brettanomyces bruxellensis, Candida stellata*, *Rhodotorula mucilaginosa, Saccharomyces* spp., *Schizosaccharomyces pombe, Torulaspora delbrueckii, Zygosaccharomyces bailii, Zygosaccharomyces bisporus, Zygosaccharomyces kombuchaensis,* and *Zygosaccharomyces microellipsoides* are also isolated from *kombucha* (Kurtzman et al., 2001; Teoh et al., 2004). Major bacterial genera present in *kombucha* are *Gluconacetobacter*. However, Marsh et al. (2014) reported the predominance of *Lactobacillus*, *Acetobacter,* and *Zygosaccharomyces*. *Lb. thailandensis, Lb. camelliae*, *Lb. plantarum, Lb. pentosus, Lb. vaccinostercus*, *Lb. pantheris, Lb. fermentum, Lb. suebicus, Ped. siamensis, Ent. casseliflavus* and *Ent. camelliae* 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).

TABLE 6 | Microorganisms isolated from some common and uncommon 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	*Lb. plantarum, Lb. paraplantarum, Lb. brevis, Lb. rhamnosus, Lb. sakei, Lb. zeae, Lb. paracasei, Ent. faecalis, Ent. faecium, Leuc. mesenteroides, Ped. pentosaceus, Ped. acidilactici, W. cibaria, W. viridescens*	Portugal	Albano et al., 2009
Androlla	Pork, coarse chopped, spices, salt	Dry, pork sausage	*Lb. sake, Lb. curvatus, Lb. plantarum*	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
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	Dry, coarse chopped, spices, salt; sausage	*Lb. sake, Lb. curvatus, Lb. plantarum*	Spain	Garcia-Fontan et al., 2007
Kargyong	Yak, beef, pork, crushed garlic, ginger, salt	Sausage like meat product, curry	*Lb. sakei, Lb. divergens, Lb. carnis, Lb. sanfranciscensis, 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
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 meat with lamb fat, 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	Species of LAB, *Micrococcus* spp.	Europe, America, Australia	Adams, 2010
Sai-krok-prieo	Pork, rice, garlic, salt	Fermented sausage	*Lb. plantarum, Lb. salivarius, Ped. pentosacuns*	Thailand	Adams, 2010
Salchichon	Pork or beef meat, fat, NaCl, spices	Dry, sausage	Species of LAB, *Staph*. spp., *Micrococcus* spp., enterobacteriaceae, molds	Spain	Fernandez-Lopez et al., 2008
Salsiccia	Chopped pork meat, spices, NaCl	Dry/ semi-dry, sausage	Species of LAB, *Staph*. spp., *Micrococcus* spp., enterobacteriaceae, yeast	Italy	Parente et al., 2001a,b
Soppressata	Chopped lean pork meat, NaCl and spices	Dry/ semi-dry, sausage	Species of LAB, *Staph*. spp., *Micrococcus* spp., enterobacteriaceae, yeast	Italy	Parente et al., 1994
Sucuk	Chopped meat, pork or beef, curing salts and various spices	Dry, sausage	Species of LAB, *Staph*. spp., *Micrococcus* spp., enterobacteriaceae	Turkey	Genccelep et al., 2008
Suka ko masu	Goat, buffalo meat, turmeric 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
Tocino	Pork, salt, sugar, potassium nitrate	Fermented cured pork	*Ped. cerevisiae, Lb. brevis, Leuc. mesenteroides*	Philippines	Alexandraki et al., 2013

Nata or bacterial cellulose produced by *Acetobacter xylinum* is a delicacy of the Philippines, eaten as candy (Chinte-Sanchez, 2008; Jagannath et al., 2010; Adams, 2014). Two types of *nata* are well-known: *nata de piña,* produced on the juice from pineapple trimmings, and *nata de coco,* produced on coconut water or coconut skim milk (Adams, 2014). Bacterial cellulose has significant potential as a food ingredient in view of its high purity, *in situ* change of flavor and color, and having the ability to form various shapes and textures (Shi et al., 2014).

Chocolate is a product of cocoa bean fermentation where *Lb. fermentum* and *Acetobacter pasteurianus* are reported as the predominating bacterial species (Lefeber et al., 2010; Papalexandratou et al., 2011). Diverse LAB species appear to be typically associated with the fermentation of cocoa

TABLE 7 | Microorganisms isolated from some common and uncommon fermented fish products of the world.

Product	Substrate/raw materials	Sensory property and nature	Microorganisms	Country	References
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
Belacan (Blacan)	Shrimp, salt	Paste, condiment	*Bacillus*, *Pediococcus*, *Lactobacillus*, *Micrococcus*, *Sarcina*, *Clostridium*, *Brevibacterium*, *Flavobacterium*, *Corynebacteria*	Malaysia	Salampessy et al., 2010
Bakasang	Fish, shrimp	Paste, condiment	*Pseudomonas*, *Enterobacter*, *Moraxella*, *Micrococcus*, *Streptococcus, Lactobacillus*, *Pseudomonas*, *Moraxella*, *Staphylococcus*, *Pediococcus* spp.	Indonesia	Ijong and Ohta, 1996
Burong Bangus	Milkfish, rice, salt, vinegar	Fermented milkfish, sauce	*Leuc. mesenteroides, Lb. plantarum, W. confusus*	Philippines	Dalmacio et al., 2011
Burong Isda	Fish, rice, salt	Fermented fish, sauce	*Leuc. mesenteroides, Ped. cerevisiae, Lb. plantarum, Strep. faecalis, Micrococcus* sp.	Philippines	Sakai et al., 1983
Budu	Marine fishes, salt, sugar	Muslim sauce, fish sauce	*Ped. halophilus, Staph. aureus, Staph. epidermidis, B. subtilis, B. laterosporus, Proteus* sp.*, Micrococcus* sp.*, Sarcina* sp.*, Corynebacterium* sp.	Thailand, Malayasia	Phithakpol et al., 1995
Gnuchi	Fish (*Schizothorax richardsonii*), salt, turmeric 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
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
Jeotkal	Fish	High-salt fermented, staple	LAB, halophilicFirmicutes including *Staphylococcus, Salimicrobium,* and *Alkalibacillus.* Also *Halanaerobium* and halophilic archaea.	Korea	Guan et al., 2011; Jung et al., 2013b
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
Kusaya	Horse mackerel, salt	Fermented dried fish	*Corynebacterium kusaya, Spirillum* sp.*, C. bifermentans, Penicillium* sp.	Japan	Alexandraki et al., 2013
Myulchijeot	Small sardine, salt	Fermented 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, salt	Fish sauce	Species of *Micrococcus*., *Pediococcus*, *Staphylococcus*., *Streptococcus*., *Sarcina*., *Bacillus*., *Lactobacillus, Corynebacterium, Pseudomonas, Halococcus, Halobacterium*	Thailand	Saisithi, 1987
Ngari	Fish (*Puntius sophore*), salt	Fermented fish	*Lact. lactis, Lb. plantarum, Lb. pobuzihii, Lb. fructosus, Lb. amylophilus, Lb. coryniformis, Ent. faecium, B. subtilis, B. pumilus, B indicu, s Micrococcus* sp.*, Staphy. cohnii* subsp. *cohnii*, *Staphy. carnosus, Tetragenococcus halophilus* subsp. *flandriensis*, *Clostridium irregular, Azorhizobium caulinodans, Candida* sp.*, Saccharomycopsis* sp.	India	Thapa et al., 2004; Devi et al., 2015

(Continued)

TABLE 7 | Continued

Product	Substrate/raw materials	Sensory property and nature	Microorganisms	Country	References
Nuoc mam	Marne fish	Fish sauce, condiment	*Bacillus* sp., *Pseudomonas* sp., *Micrococcus* sp., *Staphylococcus* sp., *Halococcus* sp., *Halobacterium salinarium*, *H. cutirubrum*	Vietnam	Lopetcharat et al., 2001
Patis	*Stolephorus* sp., *Clupea* sp., *Decapterus* sp., *Leionathus* sp., salt	Fish sauce	*Ped. halophilus, Micrococcus* sp., *Halobacterium* sp., *Halococcus* sp., *Bacillus* sp.	Philippines, Indonesia	Steinkraus, 1996
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-som (Pla-khao-sug)	Marine fish, salt, boiled rice, garlic	Fermented fish, condiment	*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
Shidal	*Puntis*	Semi-fermented, unsalted product; 4–6 months fermentation; curry/pickle	*Staphy. aureus, Micrococcus* spp., *Bacillus* spp., *E. coli*)	India, Bangladesh	Muzaddadi, 2015
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. confusa, 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
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
Tungtap	Fish	Fermented fish, paste, pickle	*Lc. lactis* subsp. *cremoris, Lc. plantarumEnt. faecium, Lb. fructosus, Lb. amylophilus, Lb. corynifomis* subsp. *torquens, Lb. plantarum*, *Lb. puhozi, B. subtilis*, *B. pumilus*, *Micrococcus,* yeasts-species of *Candida, Saccharomycopsis*	India	Thapa et al., 2004; Rapsang et al., 2011

beans in Ghana, which include *Lb. ghanensis* (Nielsen et al., 2007), *Weissella ghanensis* (de Bruyne et al., 2008a), *Lb. cacaonum,* and *Lb. fabifermentans* (de Bruyne et al., 2009), and *Weissella fabaria* (de Bruyne et al., 2010). *Fructobacillus pseudoficulneus*, *Lb. plantarum*, *Acetobacter senegalensis,* and the enterobacteria *Tatumella ptyseos* and *Tatumella citrea* are among the prevailing species during the initial phase of cocoa fermentations (Papalexandratou et al., 2011). Yeasts involved during spontaneous cocoa fermentation are *Hanseniaspora uvarum, Hanseniaspora quilliermundii*, *Issatchenkia orientalis* (*Candida krusei*), *Pichia membranifaciens*, *Sacch. Cerevisiae,* and *Kluyveromyces* species for flavor development (Schillinger et al., 2010).

Pidan is a preserved egg prepared from alkali-treated fresh duck eggs and is consumed by the Chinese, and has a strong hydrogen sulfide and ammonia smell (Ganasen and Benjakul, 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, Staph. cohnii*, *Staph. epidermidis*, *Staph. Haemolyticus,* and *Staph. warneri* are predominant in *pidan* (Wang and Fung, 1996).

Amylolytic Starters

Traditional way of culturing the essential microorganisms (consortia of filamentous molds, amylolytic, and alcohol-producing yeasts and LAB) with rice or wheat as the base in the form of dry, flattened or round balls, for production of alcoholic beverages is a remarkable discovery in the food history of Asian people, which is exclusively practiced in South-East

Asia including the Himalayan regions of India, Nepal, Bhutan, and China (Tibet; Hesseltine, 1983; Tamang, 2010a). Around 1–2% of previously prepared amylolytic starters are inoculated into the dough, and mixed cultures are allowed to develop for a short time, then dried, and used to make either alcohol or fermented foods from starchy materials (Tamang et al., 1996). Asian amylolytic starters have different vernacular names such as *marcha* in India and Nepal; *hamei, humao, phab* in India; *mana* and *manapu* of Nepal; *men* in Vietnam; *ragi* in Indonesia; *bubod* in Philippines; *chiu/chu* in China and Taiwan; *loogpang* in Thailand; *mae/dombae/buh/puh* in Cambodia; and *nuruk* in Korea (Hesseltine and Kurtzman, 1990; Nikkuni et al., 1996; Sujaya et al., 2004; Thanh et al., 2008; Yamamoto and Matsumoto, 2011; Tamang et al., 2012).

Microbial profiles of amylolytic starters of India, Nepal, and Bhutan are filamentous molds like, *Mucor circinelloides* forma *circinelloides*, *Mucor hiemalis*, *Rhi. chinensis*, and *Rhi. stolonifer* variety *lyococcus* (Tamang et al., 1988); yeasts like *Sacch. cerevisiae, Sacch. bayanus*, *Saccharomycopsis* (*Sm.*) *fibuligera, Sm. capsularis, Pichia anomala, Pic. burtonii,* and *Candida glabrata*; (Tamang and Sarkar, 1995; Shrestha et al., 2002; Tsuyoshi et al., 2005; Tamang et al., 2007; Jeyaram et al., 2008a, 2011; Chakrabarty et al., 2014); and species of LAB namely *Ped. pentosaceus*, *Lb. bifermentans,* and *Lb. brevis* (Hesseltine and Ray, 1988; Tamang and Sarkar, 1995; Tamang et al., 2007; Chakrabarty et al., 2014). A diversity of yeasts (*Candida tropicalis*, *Clavispora lusitaniae, Pichia anomala*, *Pichia ranongensis, Saccharomycopsis fibuligera*, *Sacch. cerevisiae*, *Issatchenkia* sp.); filamentous molds (*Absidia corymbifera*, *Amylomyces rouxii, Botryobasidium subcoronatum, Rhizopus oryzae*, *Rhi. microsporus*, *Xeromyces bisporus*); LAB (*Ped. pentosaceus*, *Lb. plantarum*, *Lb. brevis*, *Weissella confusa*, *Weissella paramesenteroides*); amylase-producing bacilli (*Bacillus subtilis*, *B. circulans*, *B. amyloliquefaciens*, *B. sporothermodurans*); and acetic acid bacteria (*Acetobacter orientalis*, *A. pasteurianus*) is present in *men*, a starter culture of Vietnam (Dung et al., 2006, 2007; Thanh et al., 2008).

A combination of *Asp. oryzae* and *Asp. sojae* is 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 to fermentable sugars, which are then used for the second stage yeast fermentation to make non-alcoholic fermented soybean *miso* and *shoyu* (Sugawara, 2010). *Asp. awamori, Asp. kawachii, Asp. oryzae, Asp. shirousamii,* and *Asp. sojae* have been widely used as the starter in preparation of *koji* for production of *miso, saké, shoyu, shochu* (Suganuma et al., 2007).

Alcoholic Beverages

Tamang (2010c) classified alcoholic beverages of the world into 10 types:

(1) Non-distilled and unfiltered alcoholic beverages produced by amylolytic starters e.g., kodo ko jaanr (fermented finger millets; Thapa and Tamang, 2004) and bhaati jaanr (fermented rice) of India and Nepal (Tamang and Thapa, 2006), makgeolli (fermented rice) of Korea (Jung et al., 2012).
(2) Non-distilled and filtered alcoholic beverages produced by amylolytic starters e.g., saké of Japan (Kotaka et al., 2008).
(3) Distilled alcoholic beverages produced by amylolytic starter e.g., shochu of Japan, and soju of Korea (Steinkraus, 1996).
(4) Alcoholic beverages produced by involvement of amylase in human saliva e.g., chicha of Peru (Vallejo et al., 2013).
(5) Alcoholic beverages produced by mono- (single-strain) fermentation e.g., beer (Kurtzman and Robnett, 2003).
(6) Alcoholic beverages produced from honey e.g., tej of Ethiopia (Bahiru et al., 2006).
(7) Alcoholic beverages produced from plant parts e.g., pulque of Mexico (Lappe-Oliveras et al., 2008), toddy of India (Shamala and Sreekantiah, 1988), and kanji of India (Kingston et al., 2010).
(8) Alcoholic beverages produced by malting (germination) e.g., sorghum ("Bantu") beer of South Africa (Kutyauripo et al., 2009), pito of Nigeria, and Ghana (Kolawole et al., 2013), and tchoukoutou of Benin (Greppi et al., 2013a).
(9) Alcoholic beverages prepared from fruits without distillation e.g., wine, cider.
(10) Distilled alcoholic beverages prepared from fruits and cereals e.g., whisky and brandy.

Non-distilled Mild-Alcoholic Food Beverages Produced by Amylolytic Starters

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 (Tamang, 2010c). These alcoholic beverages are mostly considered as food beverage and eaten as staple food with high calorie in many parts of Asia, e.g., *kodo ko jaanr* of the Himalayan regions in India, Nepal, Bhutan, and China (Tibet) with 5% alcohol content (Thapa and Tamang, 2004). Saccharifying activities are mostly shown by *Rhizopus* spp. and *Sm. fibuligera* whereas, liquefying activities are shown by *Sm. fibuligera* and *Sacch. cerevisiae* (Thapa and Tamang, 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 Korean *makgeolli* (prepared from rice by amylolytic starter *nuruk*), the proportion of the *Saccharomycetaceae* family increases significantly and the major bacterial phylum of the samples shifts from γ-*Proteobacteria* to *Firmicutes* (Jung et al., 2012).

Non-Distilled and Filtered Alcoholic Beverages Produced by Amylolytic Starters

Alcoholic beverages produced by amylolytic starter (*koji*) are not distilled but the extract of fermented cereals is filtered into clarified high alcohol-content liquor, like in *sake,* which is a national drink of Japan containing 15–20% alcohol (Tamang, 2010c). Improved strains of *Asp. oryzae* are used for *saké* production in industrial scale (Kotaka et al., 2008; Hirasawa et al., 2009).

Distilled Alcoholic Beverages Produced by Amylolytic Starters

This category of alcoholic drinks is the clear distillate of high alcohol content prepared as drink from fermented cereal beverages by using amylolytic starters. *Raksi* is an ethnic alcoholic (22–27% v/v) drink of the Himalayas with aromatic characteristic, and distilled from the traditionally fermented cereal beverages (Kozaki et al., 2000).

Alcoholic Beverages Produced by Human Saliva

Chicha is a unique ethnic fermented alcoholic (2–12% v/v) beverage of Andes Indian race of South America mostly in Peru, prepared from maize by human salivation process (Hayashida, 2008). *Sacch. cerevisiae, Sacch. apiculata, Sacch. pastorianus*, species of *Lactobacillus* and *Acetobacter* are present in *chicha* (Escobar et al., 1996). *Sacch. cerevisiae* was isolated from *chicha* and identified using MALDI-TOF (Vallejo et al., 2013). Species of *Lactobacillus, Bacillus, Leuconostoc, Enterococcus, Streptomyces, Enterobacter, Acinetobacter, Escherichia, Cronobacter, Klebsiella, Bifidobacterium,* and *Propioniobacterium* have been reported from *chicha* of Brazil (Puerari et al., 2015).

Alcoholic Beverages Produced from Honey

Some alcoholic beverages are produced from honey e.g., *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 *Kl. veronae*, and LAB species of *Lactobacillus*, *Streptococcus*, *Leuconostoc,* and *Pediococcus* are responsible for *tej* fermentation (Bahiru et al., 2006).

Alcoholic Beverages Produced from Plant Parts

Pulque is one of the oldest alcoholic beverages prepared from juices of the cactus (*Agave*) plant of Mexico (Steinkraus, 2002). 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, A. pomorium*, *Microbacterium arborescens*, *Flavobacterium johnsoniae*, *Gluconobacter oxydans*, and *Hafnia alvei* (Escalante et al., 2004, 2008). Yeasts isolated from *pulque* are *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).

Depending on the region, traditional alcoholic drinks prepared from palm juice called "palm wine" are known by various names, e.g., *toddy* or *tari* in India, *mu, bandji, ogogoro, nsafufuo, nsamba, mnazi, yongo, taberna, tua,* or *tubak* in West Africa and South America (Ouoba et al., 2012). Microorganisms that are responsible for *toddy* fermentation are *Sacch. cerevisiae*, *Schizosaccharomyces pombe, Acetobacter aceti, A. rancens, A. suboxydans, Leuc. dextranicum (mesenteroides), Micrococcus* sp., *Pediococcus* sp., *Bacillus* sp., and *Sarcina* sp. (Shamala and Sreekantiah, 1988).

Kanji is an ethnic Indian strong-flavored mild alcoholic beverage prepared from beet-root and carrot by natural fermentation (Batra and Millner, 1974). *Hansenlu anomala, Candida guilliermondii, C. tropicalis, Geotrichium candidum, Leuc. mesenteroides, Pediococcus* sp., *Lb. paraplantarum,* and *Lb. pentosus* are present in *kanji* (Batra and Millner, 1976; Kingston et al., 2010).

Alcoholic Beverages Produced by Malting or Germination

Bantu beer or sorghum beer of Bantu tribes of South Africa is an alcoholic beverage produced by malting or germination process (Taylor, 2003). Malted beer is common in Africa with different names e.g., as *bushera* or *muramba* in Uganda, *chibuku* in Zimbabwe, *dolo, burkutu,* and *pito* in West Africa and *ikigage* in Rwanda (Myuanja et al., 2003; Sawadogo-Lingani et al., 2007; Lyumugabe et al., 2012). Sorghum (*Sorghum caffrorum* or *S. vulgare*) is malted (Kutyauripo et al., 2009), characterized by a two-stage (lactic followed by alcoholic) fermentation, with *Lb. fermentum* as the dominating LAB species (Sawadogo-Lingani et al., 2007).

Alcoholic Beverages Produced from Fruits without Distillation

The most common example of alcoholic beverages produced from fruits without distillation is wine, which is initiated by the growth of various species of *Saccharomyces* and non-*Saccharomyces* (so-called "wild") yeasts (e.g., *Candida colliculosa, C. stellata, Hanseniaspora uvarum, Kloeckera apiculata, Kl. thermotolerans, Torulaspora delbrueckii*, *Metschnikowia pulcherrima*; Pretorius, 2000; Moreira et al., 2005; Sun et al., 2014; Walker, 2014). *Candida* sp. and *Cladosporium* sp. were isolated from fermenting white wine using mCOLD-PCR-DGGE, but had not been detected by conventional PCR (Takahashi et al., 2014). *Sacch. cerevisiae* strains developed during wine fermentations play an active role in developing the characteristics of a wine (Capece et al., 2013). *Saccharomyces Genome Database* (SGD; www.yeastgenome.org) provides free of charge access or links to comprehensive datasets comprising genomic, transcriptomic, proteomic and metabolomic information (Pretorius et al., 2015).

CONCLUSIONS

Every community in the world has distinct food culture including fermented foods and alcoholic beverages, symbolizing the heritage and socio-cultural aspects of the ethnicity. The word "culture" denotes food habits of ethnicity; another meaning for the same word "culture" is a cluster of microbial cells or inoculum, an essential biota for fermentation, often used in the microbiology. The diversity of functional microorganisms ranges from filamentous molds to enzyme-producing and alcohol-producing yeasts, and from Gram-positive to a few Gram-negative bacteria, while even *Archaea* has been ascribed roles in some fermented foods and alcoholic beverages. However, consumption of lesser known and uncommon ethnic fermented foods is declining due to the change in lifestyles that is shifting from cultural food habits to commercial foodstuffs and fast foods, drastically affecting traditional culinary practices, and also due to the climate change in some environments such as the Sahel region in Africa and the vast areas adjacent to the Gobi desert in Asia.

AUTHOR CONTRIBUTIONS

JT: contributed 50% of review works. WH, contributed 25% of review. KW contributed 25% of review.

REFERENCES

Abe, M., Takaoka, N., Idemoto, Y., Takagi, C., Imai, T., and Nakasaki, K. (2008). Characteristic fungi observed in the fermentation process for Puer tea. *Int. J. Food Microbiol.* 124, 199–203. doi: 10.1016/j.ijfoodmicro.2008.03.008

Abriouel, H., Benomar, N., Lucas, R., and Gálvez, A. (2011). Culture-independent study of the diversity of microbial populations in brines during fermentation of naturally-fermented Aloreña green table olives. *Int. J. Food Microbiol.* 144, 487–496. doi: 10.1016/j.ijfoodmicro.2010.11.006

Abriouel, H., Omar, N. B., López, R. L., Martínez-Cañamero, M., Keleke, S., and Gálvez, A. (2006). Culture-independent analysis of the microbial composition of the African traditional fermented foods *poto poto* and *dégué* by using three different DNA extraction methods. *Int. J. Food Microbiol.* 111, 228–233. doi: 10.1016/j.ijfoodmicro.2006.06.006

Adams, M. R. (2010). "Fermented meat products," in *Fermented Foods and Beverages of the World,* eds J. P. Tamang, and K. Kailasapathy (New York, NY: CRC Press, Taylor and Francis Group), 309–322.

Adams, M. R. (2014). "Vinegar," in *Encyclopaedia of Food Microbiology, 2nd Edn.,* eds C. Batt and M. A. Tortorello (Oxford: Elsevier Ltd.), 717–721.

Ahaotu, I., Anyogu, A., Njoku, O. H., Odu, N. N., Sutherland, J. P., and Ouoba, L. I. I. (2013). Molecular identification and safety of *Bacillus* species involved in the fermentation of African oil beans (*Pentaclethra macrophylla* Benth) for production of Ugba. *Int. J. Food Microbiol.* 162, 95–104.

Aidoo, K. E., and Nout, M. J. R. (2010). "Functional yeasts and molds in fermented foods and beverages," in *Fermented Foods and Beverages of the World,* eds J. P. Tamang and K. Kailasapathy (New York, NY: CRC Press, Taylor and Francis Group), 127–148. doi: 10.1201/ebk1420094954-c4

Akabanda, F., Owusu-Kwarteng, J., Tano-Debrah, K., Glover, R. L. K., Nielsen, and, D. S., and Jespersen, L. (2013). Taxonomic and molecular characterization of lactic acid bacteria and yeasts in *nunu*, a Ghanaian fermented milk product. *Food Microbiol.* 34, 277–283. doi: 10.1016/j.fm.2012.09.025

Aksu, M. I., Kaya, M., and Ockerman, H. W. (2005). Effect of modified atmosphere packaging and temperature on the shelf life of sliced Pastirma produced from frozen/thawed meat. *J. Muscle Foods* 16, 192–206. doi: 10.1111/j.1745-4573.2005.08404.x

Albano, H., van-Reenen, C. A., Todorov, S. D., Cruz, D., Fraga, L., Hogg, T., et al. (2009). Phenotypic and genetic heterogeneity of lactic acid bacteria isolated from "Alheira", a traditional fermented sausage produced in Portugal. *Meat Sci.* 82, 389–398. doi: 10.1016/j.meatsci.2009.02.009

Alegría, A., González, R., Díaz, M., and Mayo, B. (2011). Assessment of microbial populations dynamics in a blue cheese by culturing and denaturing gradient gel electrophoresis. *Curr. Microbiol.* 62, 888–893. doi: 10.1007/s00284-010-9799-7

Alexandraki, V., Tsakalidou, E., Papadimitriou, K., and Holzapfel, W. H. (2013). *Status and Trends of the Conservation and Sustainable Use of Microorganisms in Food Processes.* Commission on Genetic Resources for Food and Agriculture. *FAO* Background Study Paper No. 65.

Amoa-Awua, W. K., Terlabie, N. N., and Sakyi-Dawson, E. (2006). Screening of 42 *Bacillus* isolates for ability to ferment soybeans into *dawadawa*. *Int. J. Food Microbiol.* 106, 343–347. doi: 10.1016/j.ijfoodmicro.2005.08.016

Angelakis, E., Million, M., Henry, M., and Raoult, D. (2011). Rapid and accurate bacterial identification in probiotics and yoghurts by MALDI-TOF mass spectrometry. *J. Food Sci.* 76, M568–M572. doi: 10.1111/j.1750-3841.2011.02369.x

Asahara, N., Zhang, X. B., and Ohta, Y. (2006). Antimutagenicity and mutagen-binding activation of mutagenic pyrolyzates by microorganisms isolated from Japanese *miso. J. Sci. Food Agric.* 58, 395–401. doi: 10.1002/jsfa.2740580314

Axelsson, L., Rud, I., Naterstad, K., Blom, H., Renckens, B., Boekhorst, J., et al. (2012). Genome sequence of the naturally plasmid-free *Lactobacillus plantarum* strain NC8 (CCUG 61730). *J. Bacteriol.* 194, 2391–2392. doi: 10.1128/JB.00141-12

Azokpota, P., Hounhouigan, D. J., and Nago, M. C. (2006). Microbiological and chemical changes during the fermentation of African locust bean (*Parkia biglobosa*) to produce afitin, iru, and sonru, three traditional condiments produced in Benin. *Int. J. Food Microbiol.* 107, 304–309. doi: 10.1016/j.ijfoodmicro.2005.10.026

Bahiru, B., Mehari, T., and Ashenafi, M. (2006). Yeast and lactic acid flora of *tej*, an indigenous Ethiopian honey wine: variations within and between production units. *Food Microbiol.* 23, 277–282. doi: 10.1016/j.fm.2005.05.007

Baruzzi, F., Matarante, A., Caputo, L., and Marea, M. (2006). Molecular and physiological characterization of natural microbial communities isolated from a traditional Southern Italian processed sausage. *Meat Sci.* 72, 261–269. doi: 10.1016/j.meatsci.2005.07.013

Batra, L. R., and Millner, P. D. (1974). Some Asian fermented foods and beverages and associated fungi. *Mycologia* 66, 942–950. doi: 10.2307/3758313

Batra, L. R., and Millner, P. D. (1976). Asian fermented foods and beverages. Developments in *Indus. Microbiol.* 17, 117–128.

Bernardeau, M., Guguen, M., and Vernoux, J. P. (2006). Beneficial lactobacilli in food and feed: long-term use, biodiversity and proposals for specific and realistic safety assessments. *FEMS Microbiol. Rev.* 30, 487–513. doi: 10.1111/j.1574-6976.2006.00020.x

Blandino, A., Al-Aseeri, M. E., Pandiella, S. S., Cantero, D., and Webb, C. (2003). Cereal-based fermented foods and beverages. *Food Res. Int.* 36, 527–543. doi: 10.1016/S0963-9969(03)00009-7

Bourdichon, F., Casaregola, S., Farrokh, C., Frisvad, J. C., Gerds, M. L., Hammes, W. P., et al. (2012). Food fermentations: microorganisms with technological beneficial use. *Int. J. Food Microbiol.* 154, 87–97. doi: 10.1016/j.ijfoodmicro.2011.12.030

Brandt, M. J. (2007). Sourdough products for convenient use in baking. *Food Microbiol.* 24, 161–164. doi: 10.1016/j.fm.2006.07.010

Briggiler-Marcó, M., Capr, M. L., Quiberoni, A., Vinderola, G., Reinheimer, J. A., and Hynes, E. (2007). Nonstarter *Lactobacillus* strains as adjunct cultures for cheese making: *in vitro* characterization and performance in two model cheese. *J. Dairy Sci.* 90, 4532–4542. doi: 10.3168/jds.2007-0180

Campbell-Platt, G. (1987). *Fermented Foods of the World: A Dictionary and Guide*. London: Butterworths.

Campbell-Platt, G. (1994). Fermented foods - a world perspective. *Food Res. Int.* 27, 253–257. doi: 10.1016/0963-9969(94)90093-0

Capece, A., Siesto, G., Poeta, C., Pietrafesa, R., and Romano, P. (2013). Indigenous yeast population from Georgian aged wines produced by traditional "Kakhetian" method. *Food Microbiol.* 36, 447–455. doi: 10.1016/j.fm.2013.07.008

Chakrabarty, J., Sharma, G. D., and Tamang, J. P. (2014). Traditional technology and product characterization of some lesser-known ethnic fermented foods and beverages of North Cachar Hills District of Assam. *Indian J. Tradit. Knowl.* 13, 706–715.

Chang, H. W., Kim, K. H., Nam, Y. D., Roh, S. W., Kim, M. S., Jeon, C. O., et al. (2008). Analysis of yeast and archaeal population dynamics in kimchi using denaturing gradient gel electrophoresis. *Int. J. Food Microbiol.* 126, 159–166. doi: 10.1016/j.ijfoodmicro.2008.05.013

Chao, S. H., Kudo, Y., Tsai, Y. C., and Watanabe, K. (2012). *Lactobacillus futsaii* sp. *nov., isolated from traditional fermented mustard products of Taiwan, fu-tsai and suan-tsai. Int. J. Syst. Evol. Microbiol.* 62, 489–494. doi: 10.1099/ijs.0.030619-0

Chao, S. H., Tomii, Y., Watanabe, K., and Tsai, Y. C. (2008). Diversity of lactic acid bacteria in fermented brines used to make stinky tofu. *Int. J. Food Microbiol.* 123, 134–141. doi: 10.1016/j.ijfoodmicro.2007.12.010

Chao, S. H., Wu, R. J., Watanabe, K., and Tsai, Y. C. (2009). Diversity of lactic acid bacteria in *suan-tsai* and *fu-tsai*, traditional fermented mustard products of Taiwan. *Int. J. Food Microbiol.* 135, 203–210. doi: 10.1016/j.ijfoodmicro.2009.07.032

Chaves-López, C., Serio, A., Grande-Tovar, C. D., Cuervo-Mulet, R., Delgado-Ospina, J., and Paparella, A. (2014). Traditional fermented foods and beverages from a microbiological and nutritional perspective: the Colombian heritage. *Compr. Rev. Food Sci. Food Saf.* 13, 1031–1048. doi: 10.1111/1541-4337.12098

Chen, B., Wu, Q., and Xu, Y. (2014). Filamentous fungal diversity and community structure associated with the solid state fermentation of Chinese *Maotai*-flavor liquor. *Int. J. Food Microbiol.* 179, 80–84. doi: 10.1016/j.ijfoodmicro.2014.03.011

Chen, Y. S., Wu, H. C., Liu, C. H., Chen, H. C., and Yanagida, F. (2010). Isolation and characterization of lactic acid bacteria from jiang-sun (fermented bamboo shoots), a traditional fermented food in Taiwan. *J. Sci. Food Agric.* 90, 1977–1982. doi: 10.1002/jsfa.4034

Chen, Y. S., Wu, H. C., Lo, H. Y., Lin, W. C., Hsu, W. H., Lin, C. W., et al. (2012). Isolation and characterisation of lactic acid bacteria from *jiang-gua* (fermented cucumbers), a traditional fermented food in Taiwan. *J. Sci. Food Agric.* 92, 2069–2075. doi: 10.1002/jsfa.5583

Chen, Y. S., Yanagida, F., and Hsu, J. S. (2006). Isolation and characterization of lactic acid bacteria from *suan-tsai* (fermented mustard), a traditional fermented food in Taiwan. *J. Appl. Microbiol.* 101, 125–130. doi: 10.1111/j.1365-2672.2006.02900.x

Chettri, R., and Tamang, J. P. (2008). Microbiological evaluation of maseura, an ethnic fermented legume-based condiment of Sikkim. *J. Hill Res.* 21, 1–7.

Chettri, R., and Tamang, J. P. (2015). *Bacillus* species isolated from *Tungrymbai* and *Bekang,* naturally fermented soybean foods of India. *Int. J. Food Microbiol.* 197, 72–76. doi: 10.1016/j.ijfoodmicro.2014.12.021

Chinte-Sanchez, P. (2008). *Philippine Fermented Foods: Principles and Technology*. Quezon: The University of the Philippines Press.

Choi, S. H., Lee, M. H., Lee, S. K., and Oh, M. J. (1995). Microflora and enzyme activity of conventional *meju* and isolation of useful mould. *J. Agric. Sci. Chungnam Natl. Univ. Korea* 22, 188–197.

Choi, U. K., Kim, M. H., and Lee, N. H. (2007). The characteristics of cheonggukjang, a fermented soybean product, by the degree of germination of raw soybeans. *Food Sci. Biotechnol.* 16, 734–739.

Chokesajjawatee, N., Pornaem, S., Zo, Y. G., Kamdee, S., Luxananil, P., Wanasen, S., et al. (2009). Incidence of *Staphylococcus aureus* and associated risk factors in Nham, a Thai fermented pork product. *Food Microbiol.* 26, 547–551. doi: 10.1016/j.fm.2009.02.009

Chunhachart, O., Itoh, T., Sukchotiratana, M., Tanimoto, H., and Tahara, Y. (2006). Characterization of ©-glutamyl hydrolase produced by *Bacillus* sp. *isolated from Thai thua-nao. Biosci. Biotechnol. Biochem.* 70, 2779–2782. doi: 10.1271/bbb.60280

Cocolin, L., Aggio, D., Manzano, M., Cantoni, C., and Comi, G. (2002). An application of PCR-DGGE analysis to profile the yeast populations in raw milk. *Int. Dairy J.* 12, 407–411. doi: 10.1016/S0958-6946(02)00023-7

Cocolin, L., Alessandria, V., Dolci, P., Gorra, R., and Rantsiou, R. (2013). Culture independent methods to assess the diversity and dynamics of microbiota during food fermentation. *Int. J. Food Microbiol.* 167, 29–43. doi: 10.1016/j.ijfoodmicro.2013.05.008

Cocolin, L., Dolci, P., and Rantsiou, K. (2011). Biodiversity and dynamics of meat fermentations: the contribution of molecular methods for a better comprehension of a complex ecosystem. *Meat Sci.* 89, 296–302. doi: 10.1016/j.meatsci.2011.04.011

Cocolin, L., and Ercolini, D. (eds.). (2008). *Molecular Techniques in the Microbial Ecology of Fermented Foods. New York, NY: Springer.* doi: 10.1007/978-0-387-74520-6

Coppola, S., Fusco, V., Andolfi, R., Aponte, M., Aponte, M., Blaiotta, G., et al. (2006). Evaluation of microbial diversity during the manufacture of Fior di Latte di Agerola, a traditional raw milk pasta-filata cheese of the Naples area. *J. Dairy Res.* 73, 264–272. doi: 10.1017/S0022029906001804

Corsetti, A., and Settanni, L. (2007). Lactobacilli in sourdough fermentation. *Food Res. Int.* 40, 539–558. doi: 10.1016/j.foodres.2006.11.001

Coton, E., Desmonts, M. H., Leroy, S., Coton, M., Jamet, E., Christieans, S., et al. (2010). Biodiversity of coagulase-negative staphylococci in French cheeses, dry fermented sausages, processing environments and clinical samples. *Int. J. Food Microbiol.* 137, 221–229. doi: 10.1016/j.ijfoodmicro.2009.11.023

Dajanta, K., Apichartsrangkoon, A., Chukeatirote, E., Richard, A., and Frazier, R. A. (2011). Free-amino acid profiles of *thua nao,* a Thai fermented soybean. *Food Chem.* 125, 342–347. doi: 10.1016/j.foodchem.2010.09.002

Dajanta, K., Chukeatirote, E., Apichartsrangkoon, A., and Frazier, R. A. (2009). Enhanced aglycone production of fermented soybean products by *Bacillus* species. *Acta Biol. Szegediensis* 53, 93–98.

Dalmacio, L. M. M., Angeles, A. K. J., Larcia, L. L. H., Balolong, M., and Estacio, R. (2011). Assessment of bacterial diversity in selected Philippine fermented food products through PCR-DGGE. *Benef. Microbes* 2, 273–281. doi: 10.3920/BM2011.0017

de Bruyne, K., Camu, N., De Vuyst, L., and Vandamme, P. (2009). Lactobacillus fabifermentans sp. *nov. and Lactobacillus cacaonum* sp. nov., isolated *from Ghanaian cocoa fermentations. Int. J. Syst. Evol. Microbiol.* 59, 7–12. doi: 10.1099/ijs.0.001172-0

de Bruyne, K., Camu, N., de Vuyst, L., and Vandamme, P. (2010). *Weissella fabaria* sp. *nov., from a Ghanaian cocoa fermentation. Int. J. Syst. Evol. Microbiol.* 60, 1999–2005. doi: 10.1099/ijs.0.019323-0

de Bruyne, K., Camu, N., Lefebvre, K., De Vuyst, L., and Vandamme, P. (2008a). *Weissella ghanensis* sp. *nov., isolated from a Ghanaian cocoa fermentation. Int. J. Syst. Evol. Microbiol.* 58, 2721–2725. doi: 10.1099/ijs.0.65853-0

de Bruyne, K., Franz, C. M., Vancanneyt, M., Schillinger, U., Mozzi, F., de Valdez, G. F., et al. (2008b). *Pediococcus* argentinicus sp. *nov. from Argentinean fermented wheat flour and identification of Pediococcus species by pheS, rpoA and atpA sequence analysis. Int. J. Sys. Evo. Microbiol.* 58, 2909–2916. doi: 10.1099/ijs.0.65833-0

de Bruyne, K., Schillinger, U., Caroline, L., Boehringer, B., Cleenwerck, I., Vancanneyt, M., et al. (2007). *Leuconostoc holzapfelii* sp. *nov., isolated from Ethiopian coffee fermentation and assessment of sequence analysis of housekeeping genes for delineation of Leuconostoc species. Int. J. Sys. Evo. Microbiol.* 57, 2952–2959. doi: 10.1099/ijs.0.65292-0

de Ramesh, C. C., White, C. H., Kilara, A., and Hui Y. H. (2006). *Manufacturing Yogurt and Fermented Milks*. Oxford, Blackwell Publishing.

Desfossés-Foucault, E., Dussault-Lepage, V., Le Boucher, C., Savard, P., LaPointe, G., and Roy, D. (2012). Assessment of probiotic viability during Cheddar cheese manufacture and ripening using propidium monoazide-PCR quantification. *Front. Microbiol.* 3:350. doi: 10.3389/fmicb.2012.00350

Devi, K. R., Deka, M., and Jeyaram, K. (2015). Bacterial dynamics during yearlong spontaneous fermentation for production of *ngari*, a dry fermented fish product of Northeast India. *Int. J. Food Microbiol.* 199, 62–71. doi: 10.1016/j.ijfoodmicro.2015.01.004

de Vuyst, L., Vrancken, G., Ravyts, F., Rimaux, T., and Weckx, S. (2009). Biodiversity, ecological determinants, and metabolic exploitation of sourdough microbiota. *Food Microbiol.* 26, 666–675. doi: 10.1016/j.fm.2009.07.012

Dewan, S., and Tamang, J. P. (2006). Microbial and analytical characterization of *Chhu*, a traditional fermented milk product of the Sikkim Himalayas. *J. Sci. Indus. Res.* 65, 747–752.

Dewan, S., and Tamang, J. P. (2007). Dominant lactic acid bacteria and their technological properties isolated from the Himalayan ethnic fermented milk products. *Antonie van Leeuwenhoek* 92, 343–352. doi: 10.1007/s10482-007-9163-5

Diancourt, L., Passet, V., Chervaux, C., Garault, P., Smokvina, T., and Brisse, S. (2007). Multilocus sequence typing of *Lactobacillus casei* reveals a clonal population structure with low levels of homologous recombination. *Appl. Environ. Microbiol.* 73, 6601–6611. doi: 10.1128/AEM.01095-07

Díaz-Ruiz, G., Guyot, J. P., Ruiz-Teran, F., Morlon-Guyot, J., and Wacher, C. (2003). Microbial and physiological characterization of weakly amylolytic but fast-growing lactic acid bacteria: a functional role in supporting microbial diversity in *pozol*, a Mexican fermented maize beverage. *Appl. Environ. Microbiol.* 69, 4367–4374. doi: 10.1128/AEM.69.8.4367-4374.2003

Dirar, H. A., Harper, D. B., and Collins, M. A. (2006). Biochemical and microbiological studies on kawal, a meat substitute derived by fermentation of *Cassia obtusifolia* leaves. *J. Sci. Food Agric.* 36, 881–892. doi: 10.1002/jsfa.2740360919

Dolci, P., Alessandria, V., Rantsiou, K., and Cocolin, L. (2015). "Advanced methods for the identification, enumeration, and characterization of microorganisms in fermented foods," *in Advances in Fermented Foods and Beverages,* ed W. H. Holzapfel (London: Elsevier), 157–176. doi: 10.1016/b978-1-78242-015-6.00007-4

Doyle, M. P., and Beuchat, L. R. (2013). *Food Microbiology: Fundamentals and Frontiers, 4th Edn. Washington, DC*: *ASM Press.* doi: 10.1128/9781555818463

Dung, N. T. P., Rombouts, F. M., and Nout, M. J. R. (2006). Functionality of selected strains of moulds and yeasts from Vietnamese rice wine starters. *Food Microbiol.* 23, 331–340. doi: 10.1016/j.fm.2005.05.002

Dung, N. T. P., Rombouts, F. M., and Nout, M. J. R. (2007). Characteristics of some traditional Vietnamese starch-based rice wine starters (*Men*). *LWT Food Sci. Technol.* 40, 130–135. doi: 10.1016/j.lwt.2005.08.004

Dušková, M., Šedo, O., Kšicová, K., Zdráhal, Z., and Karpíšková, R. (2012). Identification of lactobacilli isolated from food by genotypic methods and MALDI-TOF MS. *Int. J. Food Microbiol.* 159, 107–114. doi: 10.1016/j.ijfoodmicro.2012.07.029

Encinas, J. P., Lopez-Diaz, T. M., Garcia-Lopez, M. L., Otero, A., and Moreno, B. (2000). Yeast populations on Spanish fermented sausages. *Meat Sci.* 54, 203–208.

Endo, A., Mizuno, H., and Okada, S. (2008). Monitoring the bacterial community during fermentation of sunki, an unsalted, fermented vegetable traditional to the Kiso area of Japan. *Letters Appl. Microbiol.* 47, 221–226. doi: 10.1111/j.1472-765X.2008.02404.x

Ercolini, D. (2004). PCR-DGGE fingerprinting: novel strategies for detection of microbes in food. *J. Microbiol. Methods* 56, 297–314. doi: 10.1016/j.mimet.2003.11.006

Escalante, A., Giles-Gómez, M., Hernández, G., Córdova-Aguilar, M. S., López-Munguía, A., Gosset, G., et al. (2008). Analysis of bacterial community during the fermentation of pulque, a traditional Mexican alcoholic beverage, using a polyphasic approach. *Int. J. Food Microbiol.* 124, 126–134. doi: 10.1016/j.ijfoodmicro.2008.03.003

Escalante, A., Rodríguez, M. E., Martínez, A., López-Munguía, A., Bolívar, F., and Gosset, G. (2004). Characterization of bacterial diversity in *Pulque*, a traditional Mexican alcoholic fermented beverage, as determined by 16S rDNA analysis. *FEMS Microbiol. Lett.* 2, 273–279. doi: 10.1111/j.1574-6968.2004.tb09599.x

Escobar, A., Gardner, A., and Steinkraus, K. H. (1996). "Studies of South American chichi" in *Handbook of Indigenous Fermented Food*, *2nd Edn.,* ed K. H. Steinkraus (New York, NY: Marcel Dekker, Inc.), 402–406.

Farhad, M., Kailasapathy, K., and Tamang, J. P. (2010). "Health aspects of fermented foods," in *Fermented Foods and Beverages of the World,* eds J. P. Tamang and K. Kailasapathy (New York, NY: CRC Press, Taylor and Francis Group), 391–414.

Feng, X. M., Eriksson, A. R. B., and Schnürer, J. (2005). Growth of lactic acid bacteria and *Rhizopus oligosporus* during barley tempeh fermentation. *Int. J. Food Microbiol.* 104, 249–256. doi: 10.1016/j.ijfoodmicro.2005.03.005

Fernandez-Lopez, J., Sendra, E., Sayas-Barbera, E., Navarro, C., and Perez-Alvarez, J. A. (2008). Physico-chemical and microbiological profiles of "Salchichon" (Spanish dry fermented sausage) enriched with orange fiber. *Meat Sci.* 80, 410–417. doi: 10.1016/j.meatsci.2008.01.010

Flórez, A. B., and Mayo, B. (2006). Microbial diversity and succession during the manufacture and ripening of traditional, Spanish, blue-veined Cabrales cheese, as determined by PCR261 DGGE. *Int. J. Food Microbiol.* 110, 165–171. doi: 10.1016/j.ijfoodmicro.2006.04.016

Franz, C. M. A. P., Huch, M., Mathara, J. M., Abriouel, H., Benomar, N., Reid, G., et al. (2014). African fermented foods and probiotics. *Int. J. Food Microbiol.* 190, 84–96. doi: 10.1016/j.ijfoodmicro.2014.08.033

Fujimoto, J., and Watanabe, K. (2013). Quantitative detection of viable *Bifidobacterium bifidum* BF-1 in human feces by using propidium monoazide and strain-specific primers. *Appl. Environ. Microbiol.* 79, 2182–2188. doi: 10.1128/AEM.03294-12

Ganasen, P., and Benjakul, S. (2010). Physical properties and microstructure of pidan yolk as affected by different divalent and monovalent cations. *LWT Food Sci. Technol.* 43, 77–85. doi: 10.1016/j.lwt.2009.06.007

Gänzle, M. G., Ehmann, M., and Hammes, W. P. (1998). Modeling of growth of *Lactobacillus sanfranciscensis* and *Candida milleri* in response to process parameters of sourdough fermentation. *Appl. Environ. Microbiol.* 64, 2616–2623.

Garcia-Fontan, M. C., Lorenzo, J. M., Parada, A., Franco, I., and Carballo, J. (2007). Microbiological characteristics of "Androlla", a Spanish traditional pork sausage. *Food Microbiol.* 24, 52–58. doi: 10.1016/j.fm.2006.03.007

Genccelep, H., Kaban, G., Aksu, M. I., Oz, F., and Kaya, M. (2008). Determination of biogenic amines in sucuk. *Food Control* 19, 868–872. doi: 10.1016/j.foodcont.2007.08.013

Ghosh, J., and Rajorhia, G. S. (1990). Selection of starter culture for production of indigenous fermented milk product (*Misti dahi*). *Lait* 70, 147–154. doi: 10.1051/lait:1990213

Giraffa, G., and Carminati, D. (2008). "Molecular techniques in food fermentation: principles and applications, Chap. 1" *in Molecular Techniques in the Microbial Ecology of Fermented Foods,* eds L. Cocolin, and D. Ercolini (New York, NY: Springer Science+Business Media, LCC), 1–30. doi: 10.1007/978-0-387-74520-6_1

Greppi, A., Rantsiou, K., Padonou, W., Hounhouigan, J., Jespersen, L., Jakobsen, M., et al. (2013a). Determination of yeast diversity in ogi, mawè, gowé and tchoukoutou by using culture-dependent and -independent methods. *Int. J. Food Microbiol.* 165, 84–88. doi: 10.1016/j.ijfoodmicro.2013.05.005

Greppi, A., Rantsiou, K., Padonou, W., Hounhouigan, J., Jespersen, L., Jakobsen, M., et al. (2013b). Yeast dynamics during spontaneous fermentation of mawè and tchoukoutou, two traditional products from Benin. *Int. J. Food Microbiol.* 165, 200–207. doi: 10.1016/j.ijfoodmicro.2013.05.004

Guan, L., Cho, K. H., and Lee, J. H. (2011). Analysis of the cultivable bacterial community in *jeotgal*, a Korean salted and fermented seafood, and identification of its dominant bacteria. *Food Microbiol.* 28, 101–113. doi: 10.1016/j.fm.2010.09.001

Gupta, M., Khetarpaul, N., and Chauhan, B. M. (1992). Rabadi fermentation of wheat: changes in phytic acid content and *in vitro* digestibility. *Plant Foods Human Nutr.* 42, 109–116. doi: 10.1007/BF02196463

Gupta, R. C., Mann, B., Joshi, V. K., and Prasad, D. N. (2000). Microbiological, chemical and ultrastructural characteristics of misti doi (sweetened dahi). *J. Food Sci. Technol.* 37, 54–57.

Guyot, J. P. (2010). "Fermented cereal products," in *Fermented Foods and Beverages of the World,* eds J. P.Tamang and K. Kailasapathy (New York, NY: CRC Press, Taylor and Francis Group), 247–261. doi: 10.1201/ebk1420094954-c8

Hamad, S. H., Dieng, M. M. C., Ehrmann, M. A., and Vogel, R. F. (1997). Characterisation of the bacterial flora of Sudanese sorghum flour and sorghum sourdough. *J. Appl. Microbiol.* 83, 764–770. doi: 10.1046/j.1365-2672.1997.00310.x

Hammes, W. P., Brandt, M. J., Francis, K. L., Rosenheim, J., Seitter, M. F. H., and Vogelmann, S. A. (2005). Microbial ecology of cereal fermentations. *Trends Food Sci. Technol.* 16, 4–11. doi: 10.1016/j.tifs.2004.02.010

Hammes, W. P., and and, M. G., Ganzle (1998). "Sourdough breads and related products," in *Microbiology of fermented foods, 2nd Edn.,* ed B. J. B. Wood (Glasgow: Blackie Academic and Professional), 199–216.

Han, B. Z., Beumer, R. R., Rombouts, F. M., and Nout, M. J. R. (2001). Microbiological safety and quality of commercial sufu- a Chinese fermented soybean food. *Food Control* 12, 541–547. doi: 10.1016/S0956-7135(01)00064-0

Hao, Y., Zhao, L., Zhang, H., and Zhai, Z. (2010). Identification of the bacterial biodiversity in koumiss by denaturing gradient gel electrophoresis and species-specific polymerase chain reaction. *J. Dairy Sci.* 93, 1926–1933. doi: 10.3168/jds.2009-2822

Hara, T., Chetanachit, C., Fujio, Y., and Ueda, S. (1986). Distribution of plasmids in polyglutamate-producing *Bacillus* strains isolated from "natto"–like fermented soybeans, "thua nao," in Thailand. *J. Gen. Appl. Microbiol.* 32, 241–249. doi: 10.2323/jgam.32.241

Hara, T., Hiroyuki, S., Nobuhide, I., and Shinji, K. (1995). Plasmid analysis in polyglutamate-producing *Bacillus* strain isolated from non-salty fermented soybean food, "kinema", in Nepal. *J. Gen. Appl. Microbiol.* 41, 3–9. doi: 10.2323/jgam.41.3

Harun-ur-Rashid, M., Togo, K., Useda, M., and Miyamoto, T. (2007). Probiotic characteristics of lactic acid bacteria isolated from traditional fermented milk "Dahi" in Bangladesh. *Pakistan J. Nutr.* 6, 647–652. doi: 10.3923/pjn.2007.647.652

Haruta, S., Ueno, S., Egawa, I., Hashiguchi, K., Fujii, A., Nagano, M., et al. (2006). Succession of bacterial and fungal communities during a traditional pot fermentation of rice vinegar assessed by PCR-mediated denaturing gradient gel electrophoresis. *Int. J. Food Microbiol.* 109, 79–87. doi: 10.1016/j.ijfoodmicro.2006.01.015

Hayashida, F. M. (2008). Ancient beer and modern brewers: ethnoarchaeological observations of *chicha* production in two regions of the North Coast of Peru. *J. Anthropol. Archaeol.* 27, 161–174 doi: 10.1016/j.jaa.2008.03.003

Hesseltine, C. W. (1979). Some important fermented foods of Mid-Asia, the Middle East, and Africa. *J. Am. Oil Chem. Soc.* 56, 367–374. doi: 10.1007/BF02671501

Hesseltine, C. W. (1983). Microbiology of oriental fermented foods. *Ann. Rev. Microbiol.* 37, 575–601. doi: 10.1146/annurev.mi.37.100183.003043

Hesseltine, C. W., and Kurtzman, C. P. (1990). Yeasts in amylolytic food starters. Anales del instituto de biologia de la universidad nacional autonoma de Mexico. *Serie Botanica* 60, 1–7.

Hesseltine, C. W., and Ray, M. L. (1988). Lactic acid bacteria in murcha and ragi. *J. Appl. Bacteriol.* 64, 395–401. doi: 10.1111/j.1365-2672.1988.tb05096.x

Hirasawa, T., Yamada, K., Nagahisa, K., Dinh, T. N., Furusawa, C., Katakura, Y., et al. (2009). Proteomic analysis of responses to osmotic stress in laboratory and sake-brewing strains of *Saccharomyces cerevisiae*. *Process Biochem.* 44, 647–653. doi: 10.1016/j.procbio.2009.02.004

Ho, C. C. (1986). Identity and characteristics of *Neurospora intermedia* responsible for *oncom* fermentation in Indonesia. *Food Microbiol.* 3, 115–132. doi: 10.1016/S0740-0020(86)80035-1

Holzapfel, W. (2002). Appropriate starter culture technologies for small-scale fermentation in developing countries. *Int. J. Food Microbiol.* 75, 197–212. doi: 10.1016/S0168-1605(01)00707-3

Holzapfel, W. H. (1997). Use of starter cultures in fermentation on a household scale. *Food Control* 8, 241–258. doi: 10.1016/S0956-7135(97)00017-0

Holzapfel, W. H., and Wood, B. J. B. (2014). *Lactic Acid Bacteria: Biodiversity And Taxonomy*. New York, NY: Wiley-Blackwell, 632. doi: 10.1002/9781118655252

Hong, S. W., Choi, J. Y., and Chung, K. S. (2012). Culture-based and denaturing gradient gel electrophoresis analysis of the bacterial community from chungkookjang, a traditional Korean fermented soybean food. *J. Food Sci.* 77, M572–578. doi: 10.1111/j.1750-3841.2012.02901.x

Hosono, A., Wardoyo, R., and Otani, H. (1989). Microbial flora in "dadih", a traditional fermented milk in Indonesia. *Lebensm Wiss Technol.* 22, 20–24.

Humblot, C., and Guyot, J. P. (2009). Pyrosequencing of tagged 16S rRNA gene amplicons for rapid deciphering of the microbiomes of fermented foods such as pearl millet slurries. *Appl. Environ. Microbiol.* 75, 4354–4361. doi: 10.1128/AEM.00451-09

Hwanhlem, N., Buradaleng, S., Wattanachant, S., Benjakul, S., Tani, A., and Maneerat, S. (2011). Isolation and screening of lactic acid bacteria from Thai traditional fermented fish (*Plasom*) and production of *Plasom* from selected strains. *Food Control* 22, 401–407. doi: 10.1016/j.foodcont.2010.09.010

Iacumin, L., Cecchini, F., Manzano, M., Osualdini, M., Boscolo, D., Orlic, S., et al. (2009). Description of the microflora of sourdoughs by culture-dependent and culture-independent methods. *Food Microbiol.* 26, 128–135. doi: 10.1016/j.fm.2008.10.010

Ijong, F. G., and Ohta, Y. (1996). Physicochemical and microbiological changes associated with bakasang processing - a traditional Indonesian fermented fish sauce. *J. Sci. Food Agric.* 71, 69–74.

Inatsu, Y., Nakamura, N., Yuriko, Y., Fushimi, T., Watanasritum, L., and Kawanmoto, S. (2006). Characterization of *Bacillus subtilis* strains in Thua nao, a traditional fermented soybean food in northern Thailand. *Lett. Appl. Microbiol.* 43, 237–242. doi: 10.1111/j.1472-765X.2006.01966.x

Itoh, H., Tachi, H., and Kikuchi, S. (1993). "Fish fermentation technology in Japan," in *Fish Fermentation Technology,* eds C. H. Lee, K. H. Steinkraus, and P. J. Alan Reilly (Tokyo: United Nations University Press), 177–186.

Jagannath, A., Raju, P. S., and Bawa, A. S. (2010). Comparative evaluation of bacterial cellulose (natta) as a cryoprotectant and carrier support during the freeze drying process of probiotic lactic acid bacteria. *LWT Food Sci. Technol.* 43, 1197–1203. doi: 10.1016/j.lwt.2010.03.009

Jeng, K. C., Chen, C. S., Fang, Y. P., Hou, R. C. W., and Chen, Y. S. (2007). Effect of microbial fermentation on content of statin, GABA, and polyphenols in Puerh tea. *J. Agric. Food Chem.* 55, 8787–8792. doi: 10.1021/jf071629p

Jennessen, J., Schnürer, J., Olsson, J., Samson, R. A., and Dijiksterhuis, J. (2008). Morphological characteristics of sporangiospores of the tempe fungus *Rhizopus oligosporus* differentiate it from other taxa of the *R. microsporus group. Mycol. Res.* 112, 547–563. doi: 10.1016/j.mycres.2007.11.006

Jeyaram, K., Mohendro Singh, W., Capece, A., and Romano, P. (2008a). Molecular identification of yeast species associated with 'Hamei"- a traditional starter used for rice wine production in Manipur, India. *Int. J. Food Microbiol.* 124, 115–125. doi: 10.1016/j.ijfoodmicro.2008.02.029

Jeyaram, K., Mohendro Singh, W., Premarani, T., Ranjita Devi, A., Selina Chanu, K., Talukdar, N. C., et al. (2008b). Molecular identification of dominant microflora associated with 'Hawaijar' – a traditional fermented soybean (*Glycine max* L.) food of Manipur, India. *Int. J. Food Microbiol.* 122, 259–268. doi: 10.1016/j.ijfoodmicro.2007.12.026

Jeyaram, K., Romi, W., Ah Singh, T., Devi, A. R., and Devi, S. S. (2010). Bacterial species associated with traditional starter cultures used for fermented bamboo shoot production in Manipur state of India. *Int. J. Food Microbiol.* 143, 1–8. doi: 10.1016/j.ijfoodmicro.2010.07.008

Jeyaram, K., Tamang, J. P., Capece, A., and Romano, P. P. (2011). Geographical markers for *Saccharomyces cerevisiae* strains with similar technological origins domesticated for rice-based ethnic fermented beverages production in North East India. *Antonie van Leeuwenhoek* 100, 569–578. doi: 10.1007/s10482-011-9612-z

Jianzhonga, Z., Xiaolia, L., Hanhub, J., and Mingshengb, D. (2009). Analysis of the microflora in Tibetan kefir grains using denaturing gradient gel electrophoresis. *Food Microbiol.* 26, 770–775. doi: 10.1016/j.fm.2009.04.009

Johanningsmeier, S., McFeeters, R. F., Fleming, H. P., and Thompson, R. L. (2007). Effects of *Leuconostoc mesenteroides* starter culture on fermentation of cabbage with reduced salt concentrations. *J. Food Sci.* 72, M166–M172. doi: 10.1111/j.1750-3841.2007.00372.x

Johnson, E. A., and Echavarri-Erasun, C. (2011). "Yeast Biotechnology," in *The Yeasts: A Taxonomic Study 5th Edn., Vol. 1, eds* C. Kurtzman, J. W. Fell, and T. Boekhout (Amsterdam: Elsevier), 23. doi: 10.1016/b978-0-444-52149-1.00003-3

Josephsen, J., and Jespersen, L. (2004). "Handbook of Food and Beverage Fermentation Technology," in *Starter Cultures and Fermented Products,* eds Y. H. Hui, L. Meunier-Goddik, Å. S. Hansen, J. Josephsen, W. K. Nip, P. S. Stanfield, F. Toldrá *(New York, NY*: Marcel Dekker, Inc.), 23–49.

Jung, J. Y., Lee, S. H., Jin, H. M., Hahn, Y., Madsen, E. L., and Jeon, C. O. (2013a). Metatranscriptomic analysis of lactic acid bacterial gene expression during *kimchi* fermentation. *Int. J. Food Microbiol.* 163, 171–179. doi: 10.1016/j.ijfoodmicro.2013.02.022

Jung, J. Y., Lee, S. H., Kim, J. M., Park, M. S., Bae, J. W., Hahn, Y., et al. (2011). Metagenomic analysis of kimchi, a traditional Korean fermented food. *Appl. Environ. Microbiol.* 77, 2264–2274. doi: 10.1128/AEM.02157-10

Jung, J. Y., Lee, S. H., Lee, H. J., and Jeon, C. O. (2013b). Microbial succession and metabolite changes during fermentation of saeu-jeot: traditional Korean salted seafood. *Food Microbiol.* 34, 360–368. doi: 10.1016/j.fm.2013.01.009

Jung, M. J., Nam, Y. D., Roh, S. W., and Bae, J. W. (2012). Unexpected convergence of fungal and bacterial communities during fermentation of traditional Korean alcoholic beverages inoculated with various natural starters. *Food Microbiol.* 30, 112–123. doi: 10.1016/j.fm.2011.09.008

Kahala, M., Mäki, M., Lehtovaara, A., Tapanainen, J. M., Katiska, R., Juuruskorpi, M., et al. (2008). Characterization of starter lactic acid bacteria from the Finnish fermented milk product viili. *J. Appl. Microbiol.* 105, 1929–1938. doi: 10.1111/j.1365-2672.2008.03952.x

Karki, T., Okada, S., Baba, T., Itoh, H., and Kozaki, M. (1983). Studies on the microflora of Nepalese pickles gundruk. *Nippon Shokuhin Kogyo Gakkaishi* 30, 357–367. doi: 10.3136/nskkk1962.30.357

Khanh, T. M., May, B. K., Smooker, P. M., Van, T. T. H., and Coloe, P. J. (2011). Distribution and genetic diversity of lactic acid bacteria from traditional fermented sausage. *Food Res. Int.* 44, 338–344. doi: 10.1016/j.foodres.2010.10.010

Kiers, J. L., Van laeken, A. E. A., Rombouts, F. M., and Nout, M. J. R. (2000). *In vitro* digestibility of *Bacillus* fermented soya bean. *Int. J. Food Microbiol.* 60, 163–169. doi: 10.1016/S0168-1605(00)00308-1

Kim, T. W., Lee, J. W., Kim, S. E., Park, M. H., Chang, H. C., and Kim, H. Y. (2009). Analysis of microbial communities in *doenjang*, a Korean fermented soybean paste, using nested PCR-denaturing gradient gel electrophoresis. *Int. J. Food Microbiol.* 131, 265–271. doi: 10.1016/j.ijfoodmicro.2009.03.001

Kim, Y. B., Seo, Y. G., and Lee, C. H. (1993). "Growth of microorganisms in dorsal muscle of gulbi during processing and their effect on its quality" *in Fish Fermentation Technology,* eds C. H. Lee, K. H. Steinkraus, and P. J. Alan Reilly (Tokyo: United Nations University Press), 281–289

Kimura, K., and Itoh, Y. (2007). Determination and characterization of IS*4Bsu1*-insertion loci and identification of a new insertion sequence element of the IS256 family in a natto starter. *Biosci. Biotechnol. Biochem.* 71, 2458–2464. doi: 10.1271/bbb.70223

Kingston, J. J., Radhika, M., Roshini, P. T., Raksha, M. A., Murali, H. S., and Batra, H. V. (2010). Molecular characterization of lactic acid bacteria recovered from natural fermentation of beet root and carrot Kanji. *Indian J. Microbiol.* 50, 292–298. doi: 10.1007/s12088-010-0022-0

Kiyohara, M., Koyanagi, T., Matsui, H., Yamamoto, K., Take, H., Katsuyama, Y., et al. (2012). Changes in microbiota population during fermentation of Narezushi as revealed by pyrosequencing analysis. *Biosci. Biotechnol. Biochem.* 76, 48–52. doi: 10.1271/bbb.110424

Kobayashi, T., Kimura, B., and Fujii, T. (2000a). Strictly anaerobic halophiles isolated from canned Swedish fermented herrings (Surströmming). *Int. J. Food Microbiol.* 54, 81–89. doi: 10.1016/S0168-1605(99)00172-5

Kobayashi, T., Kimura, B., and Fujii, T. (2000b). Haloanaerobium fermentans sp. *nov., a strictly anaerobic, fermentative halophile isolated from fermented puffer fish ovaries. Int. J. Syst. Evol. Microbiol.* 50, 1621–1627. doi: 10.1099/00207713-50-4-1621

Kobayashi, T., Kimura, B., and Fujii, T. (2000c). Differentiation of *Tetragenococcus* populations occurring in products and manufacturing processes of puffer fish ovaries fermented with rice-bran. *Int. J. Food Microbiol.* 56, 211–218. doi: 10.1016/S0168-1605(00)00214-2

Kolawole, O. M., Kayode, R. M. O., and Akinduyo, B. (2013). Proximate and microbial analyses of burukutu and pito produced in Ilorin, Nigeria. *Afr. J. Microbiol.* 1, 15–17.

Kotaka, A., Bando, H., Kaya, M., Kato-Murai, M., Kuroda, K., Sahara, H., et al. (2008). Direct ethanol production from barley β-glucan by sake yeast displaying *Aspergillus oryzae* β-glucosidase and endoglucanase. *J. Biosci. Bioeng.* 105, 622–627. doi: 10.1263/jbb.105.622

Kozaki, M., Tamang, J. P., Kataoka, J., Yamanaka, S., and Yoshida, S. (2000). Cereal wine *(jaanr)* and distilled wine *(raksi)* in Sikkim. *J. Brew. Soc. Japan* 95, 115–122. doi: 10.6013/jbrewsocjapan1988.95.115

Kubo, Y., Rooney, A. P., Tsukakoshi, Y., Nakagawa, R., Hasegawa, H., and Kimura, K. (2011). Phylogenetic analysis of *Bacillus subtilis* Strains applicable to natto (fermented soybean) production. *Appl. Environ. Microbiol.* 77, 6463–6469. doi: 10.1128/AEM.00448-11

Kuda, T., Izawa, Y., Yoshida, S., Koyanagi, T., Takahashi, H., and Kimura, B. (2014). Rapid identification of *Tetragenococcus halophilus* and *Tetragenococcus muriaticus*, important species in the production of salted and fermented foods, by matrix-assisted laser desorption ionization-time of flight mass spectrometry (MALDI-TOF MS). *Food Control* 35, 419–425. doi: 10.1016/j.foodcont.2013.07.039

Kurtzman, C. P., and Robnett, C. J. (2003). Phylogenetic relationship among yeasts of the "Saccharomyces complex" determined from multigene sequence analyses. *FEMS Yeast Res.* 3, 417–432. doi: 10.1016/S1567-1356(03)00012-6

Kurtzman, C. P., Robnett, C. J., and Basehoar-Powers, E. (2001). *Zygosaccharomyces kombuchaensis*, a new ascosporogenous yeast from 'Kombucha tea'. *FEMS Yeast Res.* 1, 133–138. doi: 10.1111/j.1567-1364.2001.tb00024.x

Kutyauripo, J., Parawira, W., Tinofa, S., Kudita, I., and Ndengu, C. (2009). Investigation of shelf-life extension of sorghum beer (C*hibuku*) by removing the second conversion of malt. *Int. J. Food Microbiol.* 129, 271–276. doi: 10.1016/j.ijfoodmicro.2008.12.008

Kwon, G. H., Lee, H. A., Park, J. Y., Kim, J. S., Lim, J., Park, C. S., et al. (2009). Development of a RAPD-PCR method for identification of *Bacillus* species isolated from Cheonggukjang. *Int. J. Food Microbiol.* 129, 282–287. doi: 10.1016/j.ijfoodmicro.2008.12.013

Lappe-Oliveras, P., Moreno-Terrazas, R., Arrizón-Gaviño, J., Herrera-Suárez, T., Garcia-Mendoza, A., and Gschaedler-Mathis, A. (2008). Yeasts associated with the production of Mexican alcoholic non distilled and distilled Agave beverages. *FEMS Yeast Res.* 8, 1037–1052. doi: 10.1111/j.1567-1364.2008.00430.x

Lee, C. H. (1993). "Fish fermentation technology in Korea," in *Fish Fermentation Technology*, eds C. H., Lee, K. H. Steinkraus, and P. J. Alan Reilly (Tokyo: United Nations University Press), 187–201.

Lefeber, T., Janssens, M., Camu, N., and De Vuyst, L. (2010). Kinetic analysis of strains of lactic acid bacteria and acetic acid bacteria in cocoa pulp simulation media toward development of a starter culture for cocoa bean fermentation. *Appl. Environ. Microbiol.* 76, 7708–7716. doi: 10.1128/AEM.01206-10

Lopetcharat, K., Choi, Y. J., Park, J. W., and Daeschel, M. A. (2001). Fish sauce products and manufacturing: a review. *Food Rev. Int.* 17, 65–88. doi: 10.1081/FRI-100000515

Lücke, F. K. (2015). "Quality improvement and fermentation control in meat products," in *Advances in Fermented Foods and Beverages. Improving Quality, Technologies and Health Benefits. Woodhead Publishing Series in Food Science, Technology and Nutrition No. 265.* ed W. H. Holzapfel (Cambridge: Woodhead Publishing Ltd.), 357–376. doi: 10.1016/b978-1-78242-015-6.00015-3

Lv, X.-C., Huang, X.-L., Zhang, W., Rao, P.-F., and Ni, L. (2013). Yeast diversity of traditional alcohol fermentation starters for Hong Qu glutinous rice wine brewing, revealed by culture-dependent and culture-independent methods. *Food Control* 34, 183–190. doi: 10.1016/j.foodcont.2013.04.020

Lyumugabe, F., Gros, J., Nzungize, J., Bajyana, E., and Thonart, P. (2012). Characteristics of African traditional beers brewed with sorghum malt: a review. *Biotechnol. Agron. Soc. Environ.* 16, 509–530.

Marsh, A. J., O'Sullivan, O., Hill, C. R., Ross, R. P., and Cotter, D. (2014). Sequence-based analysis of the bacterial and fungal compositions of multiple kombucha (tea fungus) samples. *Food Microbiol.* 38, 171–178. doi: 10.1016/j.fm.2013.09.003

Martín, B., Garriga, M., Hugas, M., Bover-Cid, S., Veciana-Noqués, M. T., and Aymerich, T. (2006). Molecular, technological and safety characterization of Gram-positive catalase-positive cocci from slightly fermented sausages. *Int. J. Food Microbiol.* 107, 148–158. doi: 10.1016/j.ijfoodmicro.2005.08.024

Marty, E., Buchs, J., Eugster-Meier, E., Lacroix, C., and Meile, L. (2011). Identification of staphylococci and dominant lactic acid bacteria in spontaneously fermented Swiss meat products using PCR–RFLP. *Food Microbiol.* 29, 157–166. doi: 10.1016/j.fm.2011.09.011

Mayo, B., Ammor, M. S., Delgado, S., and Alegría, A. (2010). "Fermented milk products," *in Fermented Foods and Beverages of the World,* eds J. P. Tamang, and K. Kailasapathy (New York, NY: CRC Press, Taylor and Francis Group), 263–288. doi: 10.1201/ebk1420094954-c9

Meerak, J., Iida, H., Watanabe, Y., Miyashita, M., Sato, H., Nakagawa, Y., et al. (2007). Phylogeny of ©-polyglutamic acid-producing *Bacillus* strains isolated from fermented soybean foods manufactured in Asian countries. *J. Gen. Appl. Microbiol.* 53, 315–323. doi: 10.2323/jgam.53.315

Meerak, J., Yukphan, P., Miyashita, M., Sato, H., Nakagawa, Y., and Tahara, Y. (2008). Phylogeny of ©-polyglutamic acid-producing *Bacillus* strains isolated from a fermented locust bean product manufactured in West Africa. *J. Gen. Appl. Microbiol.* 54, 159–166. doi: 10.2323/jgam.54.159

Merican, Z., and Yeoh, Q. L. (1989). "Tapai proceeding in Malaysia: a technology in transition," *in Industrialization Of Indigenous Fermented Foods*, ed K. H. Steinkraus (New York, NY: Marcel Dekker, Inc.), 169–189.

Mo, H., Zhu, Y., and Chen, Z. (2008). Microbial fermented tea – a potential source of natural food preservatives. *Trends Food Sci. Technol.* 19, 124–130. doi: 10.1016/j.tifs.2007.10.001

Moreira, N., Mendes, F., Hogg, T., and Vasconcelos, I. (2005). Alcohols, esters and heavy sulphur compounds produced by pure and mixed cultures of apiculture wine yeasts. *Int. J. Food Microbiol.* 103, 285–294. doi: 10.1016/j.ijfoodmicro.2004.12.029

Moroni, A. V., Arendt, E. K., and Bello, F. D. (2011). Biodiversity of lactic acid bacteria and yeasts in spontaneously-fermented buckwheat and teff sourdoughs. *Food Microbiol.* 28, 497–502. doi: 10.1016/j.fm.2010.10.016

Mozzi, F., Eugenia Ortiz, M., Bleckwedel, J., De Vuyst, L., and Micaela, P. (2013). Metabolomics as a tool for the comprehensive understanding of fermented and functional foods with lactic acid bacteria. *Food Res. Int.* 54, 1152–1161. doi: 10.1016/j.foodres.2012.11.010

Mugula, J. K., Ninko, S. A. M., Narvhus, J. A., and Sorhaug, T. (2003). Microbiological and fermentation characteristics of *togwa*, a Tanzanian fermented food. *Int. J. Food Microbiol.* 80, 187–199. doi: 10.1016/S0168-1605(02)00141-1

Muzaddadi, A. U. (2015). Minimisation of fermentation period of *shidal* from barbs (*Puntius* spp.). *Fishery Technol.* 52, 34–41.

Myuanja, C. M. B. K., Narvhus, J. A., Treimo, J., and Langsrud, T. (2003). Isolation, characterisation and identification of lactic acid bacteria from bushera: a Ugandan tradition al fermented beverage. *Int. J. Food Microbiol.* 80, 201–210. doi: 10.1016/S0168-1605(02)00148-4

Nagai, T., and Tamang, J. P. (2010). "Fermented soybeans and non-soybeans legume foods," in *Fermented Foods and Beverages of the World,* eds J. P. Tamang, and K. Kailasapathy (New York, NY:CRC Press, Taylor and Francis Group), 191–224.

Nakao, S. (1972). "Mame no ryori," in *Ryori no kigen*, ed S. Nakao (Tokyo: Japan Broadcast Publishing), 115–126.

Nam, Y. D., Chang, H. W., Kim, K. H., Roh, S. W., and Bae, J. W. (2009). Metatranscriptome analysis of lactic acid bacteria during kimchi fermentation with genome-probing microarrays. *Int. J. Food Microbiol.* 130, 140–146. doi: 10.1016/j.ijfoodmicro.2009.01.007

Nam, Y. D., Lee, S. Y., and Lim, S. I. (2011). Microbial community analysis of Korean soybean pastes bynext-generation sequencing. *Int. J. Food Microbiol.* 155, 36–42. doi: 10.1016/j.ijfoodmicro.2012.01.013

Nam, Y. D., Yi, S. H., and Lim, S. I. (2012). Bacterial diversity of *cheonggukjang*, a traditional Koreanfermented food, analyzed by barcoded pyrosequencing. *Food Control* 28, 135–142. doi: 10.1016/j.foodcont.2012.04.028

Nguyen, D. T. L., Van Hoorde, K., Cnockaert, M., de Brandt, E., Aerts, M., Thanh, and, L. B., et al. (2013a). A description of the lactic acid bacteria microbiota associated with the production of traditional fermented vegetables in Vietnam. *Int. J. Food Microbiol.* 163, 19–27. doi: 10.1016/j.ijfoodmicro.2013.01.024

Nguyen, D. T. L., Van Hoorde, K., Cnockaert, M., de Brandt, E., de Bruyne, K., Le, B. T., et al. (2013b). A culture-dependent and -independent approach for the identification of lactic acid bacteria associated with the production of *nem chua*, a Vietnamese fermented meat product. *Food Res. Int.* 50, 232–240. doi: 10.1016/j.foodres.2012.09.029

Nguyen, H. T., Elegado, F. B., Librojo-Basilio, N. T., Mabesa, R. C., and Dozon, E. I. (2011). Isolation and characterisation of selected lactic acid bacteria for improved processing of *Nem chua*, a traditional fermented meat from Vietnam. *Benef. Microbes* 1, 67–74. doi: 10.3920/BM2009.0001

Nielsen, D. S., Schillinger, U., Franz, C. M. A. P., Bresciani, J., Amoa-Awua, W., Holzapfel, W. H., et al. (2007). *Lactobacillus ghanensis* sp. *nov., a motile lactic acid bacterium isolated from Ghanaian cocoa fermentations. Int. J. Syst. Evol. Microbiol.* 57, 1468–1472. doi: 10.1099/ijs.0.64811-0

Nikkuni, S., Karki, T. B., Terao, T., and Suzuki, C. (1996). Microflora of mana, a Nepalese rice koji. *J. Fermen Bioeng.* 81, 168–170. doi: 10.1016/0922-338X(96)87597-0

Nishito, Y., Osana, Y., Hachiya, T., Popendorf, K., Toyoda, A., Fujiyama, A., et al. (2010). Whole genome assembly of a natto production strain *Bacillus subtilis natto* from very short read data. *BMC Genomics* 11:243. doi: 10.1186/1471-2164-11-243

Nout, M. J. R., and Aidoo, K. E. (2002). "Asian fungal fermented food," *in The Mycota,* ed H. D. Osiewacz (New York, NY: Springer-Verlag), 23–47. doi: 10.1007/978-3-662-10378-4_2

Odunfa, S. A., and Oyewole, O. B. (1997). *African fermented Foods*. London: Blackie Academic and Professional.

Oguntoyinbo, F. A., and Dodd, C. E. R. (2010). Bacterial dynamics during the spontaneous fermentation of cassava dough in *gari* production. *Food Control* 21, 306–312. doi: 10.1016/j.foodcont.2009.06.010

Oguntoyinbo, F. A., Huch, M., Cho, G. S., Schillinger, U., Holzapfel, W. H., Sanni, A. I., et al. (2010). Diversity of *Bacillus* species isolated from okpehe, a traditional fermented soup condiment from Nigeria. *J. Food Protect.* 73, 870–878.

Oguntoyinbo, F. A., Tourlomousis, P., Gasson, M. J., and Narbad, A. (2011). Analysis of bacterial communities of traditional fermented West African cereal foods using culture independent methods. *Int. J. Food Microbiol.* 145, 205–210. doi: 10.1016/j.ijfoodmicro.2010.12.025

Oguntoyinbo, F. A., Sanni Abiodun, I. S., Franz, C. M. A. P., and Holzapfel, W. H. (2007). *In vitro* fermentation studies for selection and evaluation of *Bacillus* strains as starter cultures for the production of okpehe, a traditional African fermented condiment. *Int. J. Food Microbiol.* 113, 208–218. doi: 10.1016/j.ijfoodmicro.2006.07.006

Oki, K., Dugersuren, J., Demberel, S., and Watanabe, K. (2014). Pyrosequencing analysis on the microbial diversity in Airag, Khoormog and Tarag, traditional fermented dairy products of Mongolia. *Biosci. Microbiota Food Health* 33, 53–64. doi: 10.12938/bmfh.33.53

Oki, K., Kudo, Y., and Watanabe, K. (2012). *Lactobacillus saniviri* sp. nov. and Lactobacillus senioris sp. nov., isolated from human faeces. *Int. J. Syst. Evol. Microbiol.* 62, 601–607. doi: 10.1099/ijs.0.031658-0

Oki,. K., Rai, A. K., Sato, S., Watanabe, K., and Tamang, J. P. (2011). Lactic acid bacteria isolated from ethnic preserved meat products of the Western Himalayas. *Food Microbiol.* 28, 1308–1315. doi: 10.1016/j.fm.2011.06.001

Olasupo, N. A., Odunfa, S. A., and Obayori, O. S. (2010). "Ethnic African fermented foods," in *Fermented Foods and Beverages of the World*, eds J. P. Tamang and K. Kailasapathy (New York, NY: CRC Press, Taylor and Francis Group), 323–352. doi: 10.1201/ebk1420094954-c12

Osvik, R. D., Sperstad, S., Breines, E., Hareide, E., Godfroid, J., Zhou, Z., et al. (2013). Bacterial diversity of a Masi, a South African fermented milk product, determined by clone library and denaturing gradient gel electrophoresis analysis. *African J. Microbiol. Res.* 7, 4146–4158.

Ouoba, L. I., Diawara, B., Wk, A. A., Traore, A., and Moller, P. (2004). Genotyping of starter cultures of *Bacillus subtilis* and *Bacillus pumilus* for fermentation of African locust bean (*Parkia biglobosa*) to produce Soumbala. *Int. J. Food Microbiol.* 90, 197–205. doi: 10.1016/S0168-1605(03)00302-7

Ouoba, L. I., Kando, C., Parkouda, C., Sawadogo-Lingani, H., Diawara, B., and Sutherland, J. P. (2012). The microbiology of Bandji, palm wine of Borassus akeassii from Burkina Faso: identification and genotypic diversity of yeasts, lactic acid and acetic acid bacteria. *J. Appl. Microbiol.* 113, 1428–1441. doi: 10.1111/jam.12014

Ouoba, L. I., Nyanga-Koumou, C. A., Parkouda, C., Sawadogo, H., Kobawila, S. C., Keleke, S., et al. (2010). Genotypic diversity of lactic acid bacteria isolated from African traditional alkaline-fermented foods. *J. Appl. Microbiol.* 108, 2019–2029. doi: 10.1111/j.1365-2672.2009.04603.x

Ouoba, L. I., Parkouda, C., Diawara, B., Scotti, C., and Varnam, A. (2008). Identification of *Bacillus* spp. from Bikalga, fermented seeds of *Hibiscus sabdariffa*: phenotypic and genotypic characterization. *J. Appl. Microbiol.* 104, 122–131. doi: 10.1111/j.1365-2672.2007.03550.x

Oyewole, O. B., Olatunji, O. O., and Odunfa, S. A. (2004). A process technology for conversion of dried cassava chips into 'gari'. *Nigerian Food J.* 22, 65–76.

Papalexandratou, Z., Vrancken, G., De Bruyne, K., Vandamme, P., and de Vuyst, L. (2011).Spontaneous organic cocoa bean box fermentations in Brazil are characterized by a restricted species diversity of lactic acid bacteria and acetic acid bacteria. *Food Microbiol.* 28, 1326–1338. doi: 10.1016/j.fm.2011.06.003

Parente, E., and Cogan, T. M. (2004). "Starter cultures: general aspects," in *Cheese: Chemistry, Physics and Microbiology, 3rd Edn,* ed P. O. Fox (Oxford: Elsevier), 123–147. doi: 10.1016/S1874-558X(04)80065-4

Parente, E., Martuscelli, M., Gardini, F., Grieco, S., Crudele, M. A., and and, G., Suzzi, G. (2001b). Evolution of microbial populations and biogenic amine production in dry sausages produced in Southern Italy. *J. Appl. Microbiol.* 90, 882–891. doi: 10.1046/j.1365-2672.2001.01322.x

Parente, E. S., Di Matteo, M., Spagna Musso, S., and Crudele, M. A. (1994). Use of commercial starter cultures in the production of soppressa lucana, a fermented sausage from Basilicata. *Italian J. Sci.* 6, 59–69.

Parente, E. S., Grieco, S., and Crudele, M. A. (2001a). Phenotypic diversity of lactic acid bacteria isolated from fermented sausages produced in Basilicata (Southern Italy). *J. Appl. Microbiol.* 90, 943–952. doi: 10.1046/j.1365-2672.2001.01328.x

Park, C., Choi, J. C., Choi, Y. H., Nakamura, H., Shimanouchi, K., Horiuchi, T., et al. (2005). Synthesis of super-high-molecular-weight poly-©-glutamic acid by *Bacillus subtilis* subsp. chungkookjang. *J. Mol. Catal. B. Enzym.* 35, 128–133. doi: 10.1016/j.molcatb.2005.06.007

Park, E. J., Chang, H. W., Kim, K. H., Nam, Y. D., Roh, S. W., and Bae, J. W. (2009). Application of quantitative real-time PCR for enumeration of total bacterial, archaeal, and yeast populations in kimchi. *J. Microbiol.* 47, 682–685. doi: 10.1007/s12275-009-0297-1

Park, E. J., Chun, J., Cha, C. J., Park, W. S., Jeon, C. O., and Bae, J. W. (2012). Bacterial community analysis during fermentation of ten representative kinds of kimchi with barcoded pyrosequencing. *Food Microbiol.* 30, 197–204. doi: 10.1016/j.fm.2011.10.011

Park, J. M., Shin, J. H., Lee, D. W., Song, J. C., Suh, H. J., Chang, U. J., et al. (2010). Identification of the lactic acid bacteria in kimchi according to initial and over-ripened fermentation using PCR and 16S rRNA gene sequence analysis. *Food Sci. Biotechnol.* 19, 541–546. doi: 10.1007/s10068-010-0075-1

Parkouda, C., Nielsen, D. S., Azokpota, P., Ouoba, L. I. I., Amoa-Awua, W. K., Thorsen, L., et al. (2009). The microbiology of alkaline-fermentation of indigenous seeds used as food condiments in Africa and Asia. *Critical Rev. Microbiol.* 35, 139–156. doi: 10.1080/10408410902793056

Patil, M. M., Pal, A., Anand, T., and Ramana, K. V. (2010). Isolation and characterization of lactic acid bacteria from curd and cucumber. *Indian J. Biotechnol.* 9, 166–172.

Pederson, C. S. (1979). *Microbiology of Food Fermentations, 2nd edition*. Westport, AVI Publishing Company.

Phithakpol, B., Varanyanond, W., Reungmaneepaitoon, S., and Wood, H. (1995). *The Traditional Fermented Foods of Thailand*. Kuala Lumpur: ASEAN Food Handling Bureau.

Picozzi, C., Bonacina, G., Vigentini, I., and Foschino, R. (2010). Genetic diversity in Italian *Lactobacillus sanfranciscensis* strains assessed by multilocus sequence typing and pulsed field gel electrophoresis analyses. *Microbiol.* 156, 2035–2045. doi: 10.1099/mic.0.037341-0

Plengvidhya, V., Breidt, F., and Fleming, H. P. (2007). Use of RAPD-PCR as a method to follow the progress of starter cultures in sauerkraut fermentation. *Int. J. Food Microbiol.* 93, 287–296. doi: 10.1016/j.ijfoodmicro.2003.11.010

Pretorius, I. S. (2000). Tailoring wine yeast for the new millennium: novel approaches to the ancient art of winemaking. *Yeast* 16, 675–729. doi: 10.1002/1097-0061(20000615)16:8<675::AID-YEA585>3.0.CO;2-B

Pretorius, I. S., Curtin, C. D., and Chambers, P. J. (2015). "Designing wine yeast for the future, Chap. 9," in *Advances in fermented foods and beverages. Improving quality, technologies and health benefits. Woodhead Publishing Series in Food Science, Technology and Nutrition No. 265*. ed W. H. Holzapfel (Cambridge: Woodhead Publishing Ltd.), 197–226.

Puerari, C., Magalhâes-Guedes, T. M., and Schwan, R. F. (2015). Physicochemical and microbiological characterization of chicha, a rice-based fermented beverage produced by Umutina Brazilian Amerindians. *Food Microbiol.* 46, 210–217. doi: 10.1016/j.fm.2014.08.009

Puspito, H., and Fleet, G. H. (1985). Microbiology of *sayur asin* fermentation. *Appl. Microbiol. Biotechnol.* 22, 442–445. doi: 10.1007/BF00252788

Qin, H., Yang, H., Qiao, Z., Gao, S., and Liu, Z. (2013). Identification and characterization of a *Bacillus subtilis* strain HB-1 isolated from *Yando*u, a fermented soybean food in China. *Food Control* 31, 22–27. doi: 10.1016/j.foodcont.2012.10.004

Quigley, L., O'Sullivan, O., Beresford, T. P., Ross, R. P., Fitzgerald, G. F., and Cotter, P. D. (2011). Molecular approaches to analysing the microbial composition of raw milk and raw milk cheese. *Int. J. Food Microbiol.* 150, 81–94. doi: 10.1016/j.ijfoodmicro.2011.08.001

Rai, A. K., Palni, U., and Tamang, J. P. (2010). Microbiological studies of ethnic meat products of the Eastern Himalayas. *Meat Sci.* 85, 560–567. doi: 10.1016/j.meatsci.2010.03.006

Ramos, C. L., de Almeida, E. G., de Melo Pereira, G. V., Cardoso, P. G., Dias, E. S., and Schwan, R. F. (2010). Determination of dynamic characteristics of microbiota in a fermented beverage produced by Brazilian Amerindians using culture-dependent and culture-independent methods. *Int. J. Food Microbiol.* 140, 225–231. doi: 10.1016/j.ijfoodmicro.2010.03.029

Rani, D. K., and Soni, S. K. (2007). "Applications and commercial uses of microorganisms," in *Microbes: a source of energy for 21st century*. ed S. K. Soni (Delhi : Jai Bharat Printing Press), 71–126.

Rapsang, G. F., Kumar, R., and Joshi, S. R. (2011). Identification of *Lactobacillus puhozihii* from tungtap: A traditionally fermented fish food, and analysis of its bacteriocinogenic potential. *African J. Biotechnol.* 10, 12237–12243.

Rhee, S. J., Lee, J. E., and Lee, C. H. (2011). Importance of lactic acid bacteria in Asian fermented foods. *Microbial Cell Factories* 10, 1–13. doi: 10.1186/1475-2859-10-S1-S5

Robert, H., Gabriel, V., and Fontagné-Faucher, C. (2009). Biodiversity of lactic acid bacteria in French wheat sourdough as determined by molecular characterization using species-specific PCR. *Int. J. Food Microbiol.* 135, 53–59. doi: 10.1016/j.ijfoodmicro.2009.07.006

Romi, W., Ahmed, G., and Jeyaram, K. (2015). Three-phase succession of autochthonous lactic acid bacteria to reach a stable ecosystem within 7 days of natural bamboo shoot fermentation as revealed by different molecular approaches. *Mol. Ecol.* 13, 3372–3389. doi: 10.1111/mec.13237

Saisithi, P. (1987). Traditional fermented fish products with special reference to Thai products. *ASEAN Food J.* 3, 3–10

Saithong, P., Panthavee, W., Boonyaratanakornkit, M., and Sikkhamondhol, C. (2010). Use of a starter culture of lactic acid bacteria in *plaa-som*, a Thai fermented fish. *J. Biosci. Bioeng.* 110, 553–557. doi: 10.1016/j.jbiosc.2010.06.004

Sakai, H., Caldo, G. A., and Kozaki, M. (1983).Yeast-flora in red *burong-isda* a fermented fish food from the Philippines. *J. Agric. Sci. (Tokyo)* 28, 181–185.

Sakamoto, N., Tanaka, S., Sonomoto, K., and Nakayama, J. (2011). 16S rRNA pyrosequencing-based investigation of the bacterial community in nukadoko, a pickling bad of fermented rice bran. *Int. J. Food Microbiol.* 144, 352–359. doi: 10.1016/j.ijfoodmicro.2010.10.017

Salampessy, J., Kailasapathy, K., and Thapa, N. (2010). Fermented fish products. in *Fermented Foods and Beverages of the World,* eds J. P. Tamang and K. Kailasapathy (New York, NY: CRC Press, Taylor and Francis Group), 289–307.

Salminen, S., Wright, A. V., and Ouwehand, A. (2004). *Lactic Acid Bacteria Microbiology and Functional Aspects, 3rd Edn.*, New York, NY: Marcel Dekker.

Sarkar, P. K., Hasenack, B., and Nout, M. J. R. (2002). Diversity and functionality of *Bacillus* and related genera isolated from spontaneously fermented soybeans (Indian Kinema) and locust beans (African Soumbala). *Int. J. Food Microbiol.* 77, 175–186. doi: 10.1016/S0168-1605(02)00124-1

Sarkar, P. K., and Tamang, J. P. (1994). The influence of process variables and inoculum composition on the sensory quality of kinema. *Food Microbiol.* 11, 317–325. doi: 10.1006/fmic.1994.1036

Sarkar, P. K., Tamang, J. P., Cook, P. E., and Owens, J. D. (1994). Kinema-a traditional soybean fermented food: proximate composition and microflora. *Food Microbiol.* 11, 47–55. doi: 10.1006/fmic.1994.1007

Sarkar, S. (2008). Innovations in Indian fermented milk products-a review. *Food Biotechnol.* 22, 78–97. doi: 10.1080/08905430701864025

Sato, H., Torimura, M., Kitahara, M., Ohkuma, M., Hotta, Y., and Tamura, H. (2012). Characterization of the *Lactobacillus casei* group based on the profiling of ribosomal proteins coded in S10-spc-alpha operons as observed by MALDI-TOF MS. *Sys. Appl. Microbiol.* 35, 447–454. doi: 10.1016/j.syapm.2012.08.008

Savadogo, A., Tapi, A., Chollet, M., Wathelet, B., Traor,é, A. S., and Jacques, P. (2011). Identification of surfactin producing strains in *Soumbala* and *Bikalga* fermented condiments using Polymerase chain reaction and matrix assisted laser desorption/ionization-mass spectrometry methods. *Int. J. Food Microbiol.* 151, 299–306. doi: 10.1016/j.ijfoodmicro.2011.09.022

Sawadogo-Lingani, H., Lei, V., Diawara, B., Nielsen, D. S., Møller, P. L., Traor,é, A. S., et al. (2007). The biodivesity of predominant lactic acid bacteria in dolo and pito wort for the production of sorghum beer. *J. Appl. Microbiol.* 103, 765–777. doi: 10.1111/j.1365-2672.2007.03306.x

Sawamura, S. (1906). On the microorganisms of natto. *Bull. Coll. Agri. Tokyo Imperial Univ*. 7, 107–110.

Schillinger, U., Ban-Koffi, L., and Franz, C. M. A. P. (2010). "Tea, coffee and cacao," in *Fermented Foods and Beverages of the World,* eds J. P. Tamang, and K. Kailasapathy (New York, NY: CRC Press, Taylor and Francis Group), 353–375. doi: 10.1201/ebk1420094954-c13

Sengun, I. Y., and Karabiyikli, S. (2011). Importance of acetic acid bacteria in food industry. *Food Control* 22, 647–665 doi: 10.1016/j.foodcont.2010.11.008

Sengun, I. Y., Nielsen, D. S., Karapinar, M., and Jakobsen, M. (2009). Identification of lactic acid bacteria isolated from Tarhana, a traditional Turkish fermented food. *Int. J. Food Microbiol.* 135, 105–111. doi: 10.1016/j.ijfoodmicro.2009.07.033

Shamala, T. R., and Sreekantiah, K. R. (1988). Microbiological and biochemical studies on traditional Indian palm wine fermentation. *Food Microbiol.* 5, 157–162. doi: 10.1016/0740-0020(88)90014-7

Shrestha, H., Nand, K., and Rati, E. R. (2002). Microbiological profile of murcha starters and physico-chemical characteristics of poko, a rice based traditional food products of Nepal. *Food Biotechnol.* 16, 1–15. doi: 10.1081/FBT-120004198

Shi, Z., Zhang, Y., Phillips, G. O., and Yang, G. (2014). Utilization of bacterial cellulose in food. *Food Hydrocolloids* 35, 539–545. doi: 10.1016/j.foodhyd.2013.07.012

Shin, D. H., Kwon, D. Y., Kim, Y. S., and Jeong, D. Y. (2012). *Science and Technology of Korean Gochujang*. Seoul: Public Health Edu.

Shin, M. S., Han, S. K., Ryu, J. S., Kim, K. S., and Lee, W. K. (2008). Isolation and partial characterization of a bacteriocin produced by *Pediococcus pentosaceus* K23-2 isolated from kimchi. *J. Appl. Microbiol.* 105, 331–339. doi: 10.1111/j.1365-2672.2008.03770.x

Shon, M. Y., Lee, J., Choi, J. H., Choi, S. Y., Nam, S. H., Seo, K. I., et al. (2007). Antioxidant and free radical scavenging activity of methanol extract of chungkukjang. *J. Food Comp. Anal.* 20, 113–118. doi: 10.1016/j.jfca.2006.08.003

Singh, D., and Singh, J. (2014). Shrikhand: a delicious and healthful traditional Indian fermented dairy dessert. *Trends Biosci.* 7, 153–155.

Singh, T. A., Devi, K. R., Ahmed, G., and Jeyaram, K. (2014). Microbial and endogenous origin of fibrinolytic activity in traditional fermented foods of Northeast India. *Food Res. Int.* 55, 356–362. doi: 10.1016/j.foodres.2013.11.028

Solieri, L., and Giudici, P. (2008). Yeasts associated to traditional balsamic vinegar: ecological and technological features. *Int. J. Food Microbiol.* 125, 36–45. doi: 10.1016/j.ijfoodmicro.2007.06.022

Sonar, R. N., and Halami, P. M. (2014). Phenotypic identification and technological attributes of native lactic acid bacteria present in fermented bamboo shoot products from North-East India. *J. Food Sci. Technol*. doi: 10.1007/s13197-014-1456-x

Soni, S. K., Sandhu, D. K., Vilkhu, K. S., and Kamra, N. (1986). Microbiological studies on Dosa fermentation. *Food Microbiol.* 3, 45–53. doi: 10.1016/S0740-0020(86)80025-9

Sridevi, J., Halami, P. M., and Vijayendra, S. V. N. (2010). Selection of starter cultures for *idli* batter fermentation and their effect on quality of *idli*. *J. Food Sci. Technol.* 47, 557–563. doi: 10.1007/s13197-010-0101-6

Steinkraus, K. H. (1994). Nutritional significance of fermented foods. *Food Res. Int.* 27, 259–267. doi: 10.1016/0963-9969(94)90094-9

Steinkraus, K. H. (1996). *Handbook of Indigenous Fermented Food, 2nd Edn*. New York, NY: Marcel Dekker, Inc.

Steinkraus, K. H. (1997). Classification of fermented foods: worldwide review of household fermentation techniques. *Food Control* 8, 331–317. doi: 10.1016/S0956-7135(97)00050-9

Steinkraus, K. H. (2002). Fermentations in world food processing. *Comprehensive Rev. Food Sci. Food Safety* 1, 23–32. doi: 10.1111/j.1541-4337.2002.tb00004.x

Steinkraus, K. H. (2004). *Industrialization of Indigenous Fermented Foods*. New York, NY: Marcel Dekker, Inc.

Steinkraus, K. H., van Veer, A. G., and Thiebeau, D. B. (1967). Studies on idli-an Indian fermented black gram-rice food. *Food Technol.* 21, 110–113.

Stevens, H. C., and Nabors, L. (2009). Microbial food cultures: a regulatory update. *Food Technol. (Chicago)* 63, 36–41.

Stiles, M. E., and Holzapfel, W. H. (1997). Lactic acid bacteria of foods and their current taxonomy. *Int. J. Food Microbiol.* 36, 1–29. doi: 10.1016/S0168-1605(96)01233-0

Suganuma, T., Fujita, K., and Kitahara, K. (2007). Some distinguishable properties between acid-stable and neutral types of α-amylases from acid-producing *koji*. *J. Biosci. Bioeng.* 104, 353–362. doi: 10.1263/jbb.104.353

Sugawara, E. (2010). "Fermented soybean pastes *miso* and *shoyu* with reference to aroma," in *Fermented Foods and Beverages of the World,* eds J. P. Tamang and K. Kailasapathy, (New York, NY: CRC Press, Taylor and Francis Group), 225–245. doi: 10.1201/ebk1420094954-c7

Sujaya, I., Antara, N., Sone, T., Tamura, Y., Aryanta, W., Yokota, A., et al. (2004). Identification and characterization of yeasts in brem, a traditional Balinese rice wine. *World J. Microbiol. Biotechnol.* 20, 143–150. doi: 10.1023/B:WIBI.0000021727.69508.19

Sukontasing, S., Tanasupawat, S., Moonmangmee, S., Lee, J. S., and Suzuki, K. (2007). *Enterococcus camelliae* sp. nov., isolated from fermented tea leaves in Thailand. *Int. J. Sys. Evo. Microbiol.* 57, 2151–2154. doi: 10.1099/ijs.0.65109-0

Sumino, T., Endo, E., Kageyama, A. S., Chihihara, R., and Yamada, K. (2003). Various Components and Bacteria of Furu (Soybean Cheese). *J. Cookery Sci. Japan* 36, 157–163. doi: 10.11402/cookeryscience1995.36.2_157

Sun, S. Y., Gong, H. S., Jiang, X. M., and Zhao, Y. P. (2014). Selected non-*Saccharomyces* wine yeasts in controlled multistarter fermentations with *Saccharomyces cerevisiae* on alcoholic fermentation behaviour and wine aroma of cherry wines. *Food Microbiol.* 44, 15–23. doi: 10.1016/j.fm.2014.05.007

Suprianto Ohba, R., Koga, T., and Ueda, S. (1989). Liquefaction of glutinous rice and aroma formation in tapé preparation by ragi. *J. Ferment Bioeng.* 64, 249–252. doi: 10.1016/0922-338X(89)90227-4

Takahashi, M., Masaki, K., Mizuno, A., and Goto-Yamamoto, N. (2014). Modified COLD-PCR for detection of minor microorganisms in wine samples during the fermentation. *Food Microbiol.* 39, 74–80. doi: 10.1016/j.fm.2013.11.009

Tamang, B., and Tamang, J. P. (2007). Role of lactic acid bacteria and their functional properties in *Goyang*, a fermented leafy vegetable product of the Sherpas. *J. Hill Res.* 20, 53–61.

Tamang, B., and Tamang, J. P. (2009). Lactic acid bacteria isolated from indigenous fermented bamboo products of Arunachal Pradesh in India and their functionality. *Food Biotechnol.* 23, 133–147. doi: 10.1080/08905430902875945

Tamang, B., and Tamang, J. P. (2010). *In situ* fermentation dynamics during production of *gundruk* and *khalpi*, ethnic fermented vegetables products of the Himalayas. *Indian J. Microbiol.* 50, 93–98. doi: 10.1007/s12088-010-0058-1

Tamang, B., Tamang, J. P., Schillinger, U., Franz, C. M. A. P., Gores, M., and Holzapfel, W. H. (2008). Phenotypic and genotypic identification of lactic acid bacteria isolated from ethnic fermented tender bamboo shoots of North East India. *Int. J. Food Microbiol.* 121, 35–40. doi: 10.1016/j.ijfoodmicro.2007.10.009

Tamang, J. P. (2003). Native microorganisms in fermentation of kinema. *Indian J. Microbiol.* 43, 127–130.

Tamang, J. P. (2010a). *Himalayan Fermented Foods: Microbiology, Nutrition, and Ethnic Values.* New York, NY: CRC Press, Taylor and Francis Group.

Tamang, J. P. (2010b). Diversity of fermented foods, In: Tamang JP, Kailasapathy, K. *(Eds.) Fermented Foods and Beverages of the World, CRC Press, Taylor and Francis Group, New York*, 41–84. doi: 10.1201/ebk1420094954-c2

Tamang, J. P. (2010c). "Diversity of fermented beverages," in *Fermented Foods and Beverages of the World,* eds J. P. Tamang, and K. Kailasapathy (New York, NY: CRC Press, Taylor and Francis Group), 85–125.

Tamang, J. P. (2014). "Biochemical and modern identification techniques - microfloras of fermented foods," in: *Encyclopaedia of Food Microbiology, 2nd Edn.,* eds C. Batt, and M. A. Tortorello (Oxford: Elsevier Ltd.), 250–258.

Tamang, J. P. (2015a). *Health Benefits of Fermented Foods and Beverages*. New York, NY: CRC Press, Taylor and Francis Group

Tamang, J. P. (2015b). Naturally fermented ethnic soybean foods of India. *J. Ethnic Foods* 2, 8–17. doi: 10.1016/j.jef.2015.02.003

Tamang, J. P., Dewan, S., Tamang, B., Rai, A., Schillinger, U., and Holzapfel, W. H. (2007). Lactic acid bacteria in *Hamei* and *Marcha* of North East India. *Indian J. Microbiol.* 47, 119–125. doi: 10.1007/s12088-007-0024-8

Tamang, J. P., Dewan, S., Thapa, S., Olasupo, N. A., Schillinger, U., Wijaya, A., et al. (2000). Identification and enzymatic profiles of predominant lactic acid bacteria isolated from soft-variety *chhurpi*, a traditional cheese typical of the Sikkim Himalayas. *Food Biotechnol.* 14, 99–112. doi: 10.1080/08905430009549982

Tamang, J. P., and Fleet, G. H. (2009). "Yeasts diversity in fermented foods and beverages," in *Yeasts Biotechnology: Diversity and Applications,* eds T. Satyanarayana, and G. Kunze, (New York, NY: Springer), 169–198. doi: 10.1007/978-1-4020-8292-4_9

Tamang, J. P., and Nikkuni, S. (1996). Selection of starter culture for production of kinema, fermented soybean food of the Himalaya. *World J. Microbiol. Biotechnol.* 12, 629–635. doi: 10.1007/BF00327727

Tamang, J. P., and Samuel, D. (2010). "Dietary cultures and antiquity of fermented foods and beverages," in *Fermented Foods and Beverages of the World* eds J. P. Tamang, and K. Kailasapathy (London: CRC press), 1–40. doi: 10.1201/ebk1420094954-c1

Tamang, J. P., and Sarkar, P. K. (1993). Sinki - a traditional lactic acid fermented radish tap root product. *J. Gen. Appl. Microbiol.* 39, 395–408. doi: 10.2323/jgam.39.395

Tamang, J. P., and Sarkar, P. K. (1995). Microflora of murcha: an amylolytic fermentation starter. *Microbios* 81, 115–122.

Tamang, J. P., and Sarkar, P. K. (1996). Microbiology of mesu, a traditional fermented bamboo shoot product. *Int. J. Food Microbiol.* 29, 49–58. doi: 10.1016/0168-1605(95)00021-6

Tamang, J. P., Sarkar, P. K., and Hesseltine, C. W. (1988). Traditional fermented foods and beverages of Darjeeling and Sikkim - a review. *J. Sci. Food Agric.* 44, 375–385. doi: 10.1002/jsfa.2740440410

Tamang, J. P., Tamang, B., Schillinger, U., Franz, C. M. A. P., Gores, M., and Holzapfel, W. H. (2005). Identification of predominant lactic acid bacteria isolated from traditional fermented vegetable products of the Eastern Himalayas. *Int. J. Food Microbiol.* 105, 347–356. doi: 10.1016/j.ijfoodmicro.2005.04.024

Tamang, J. P., Tamang, B., Schillinger, U., Guigas, C., and Holzapfel, W. H. (2009). Functional properties of lactic acid bacteria isolated from ethnic fermented vegetables of the Himalayas. *Int. J. Food Microbiol.* 135, 28–33. doi: 10.1016/j.ijfoodmicro.2009.07.016

Tamang, J. P., Tamang, N., Thapa, S., Dewan, S., Tamang, B. M., Yonzan, H., et al. (2012). Microorganisms and nutritional value of ethnic fermented foods and alcoholic beverages of North East India. *Indian J. Traditional Know.* 11, 7–25.

Tamang, J. P., Thapa, N., Tamang, B., Rai, A., and Chettri, R. (2015). "*Microorganisms in fermented foods and beverages,* Chap. 1,"*in Health Benefits of Fermented Foods ed J. P. Tamang,* (New York, NY: CRC Press, Taylor *and Francis Group),* 1–110.

Tamang, J. P., and Thapa, S. (2006). Fermentation dynamics during production of bhaati jaanr, a traditional fermented rice beverage of the Eastern Himalayas. *Food Biotechnol.* 20, 251–261. doi: 10.1080/08905430600904476

Tamang, J. P., Thapa, S., Dewan, S., Jojima, Y., Fudou, R., and Yamanaka, S. (2002). Phylogenetic analysis of *Bacillus* strains isolated from fermented soybean foods of Asia: *kinema, chungkokjang* and *natto*. *J. Hill Res.* 15, 56–62.

Tamang, J. P., Thapa, S., Tamang, N., and Rai, B. (1996). Indigenous fermented food beverages of Darjeeling hills and Sikkim: process and product characterization. *J. Hill Res.* 9, 401–411.

Tamime, A. Y., and Robinson, R. K. (2007). *Yoghurt Science and Technology*. Cambridge: Woodhead Publishing Ltd.

Tanasupawat, S., Pakdeeto, A., Thawai, C., Yukphan, P., and Okada, S. (2007). Identification of lactic acid bacteria from fermented tea leaves (miang) in Thailand and proposals of *Lactobacillus thailandensis* sp. *nov., Lactobacillus camelliae sp. nov., and Pediococcus siamensis sp. nov. J. Gen. Appl. Microbiol.* 53, 7–15. doi: 10.2323/jgam.53.7

Tanigawa, K., Kawabata, H., and Watanabe, K. (2010). Identification and typing of *Lactococcus lactis* by matrix-assisted laser desorption ionization – time-of-flight mass spectrometry. *Appl. Environ. Microbiol.* 76, 4055–4062. doi: 10.1128/AEM.02698-09

Tanigawa, K., and Watanabe, K. (2011). Multilocus sequence typing reveals a novel subspeciation of *Lactobacillus delbrueckii*. *Microbiol.* 157, 727–738. doi: 10.1099/mic.0.043240-0

Taylor, J. R. N. (2003). "Beverages from sorghum and millet," in *Encyclopedia of Food Sciences and Nutrition, 2nd Edn.,* eds B. Caballero, L. C. Trugo, P. M. Finglas (London: Academic Press), 2352–2359. doi: 10.1016/B0-12-227055-X/00454-5

Teoh, A. L., Heard, G., and Cox, J. (2004). Yeasts ecology of Kombucha fermentation. *Int. J. Food Microbiol.* 95, 119–126. doi: 10.1016/j.ijfoodmicro.2003.12.020

Thanh, V. N., Mai, L. T., and Tuan, D. A. (2008). Microbial diversity of traditional Vietnamese alcohol fermentation starters (*banh men*) as determined by PCR-mediated DGGE. *Int. J. Food Microbiol.* 128, 268–273. doi: 10.1016/j.ijfoodmicro.2008.08.020

Thapa, N., Pal, J., and Tamang, J. P. (2004). Microbial diversity in ngari, hentak and tungtap, fermented fish products of Northeast India. *World J. Microbiol. Biotechnol.* 20, 599–607. doi: 10.1023/B:WIBI.0000043171.91027.7e

Thapa, N., Pal, J., and Tamang, J. P. (2006). Phenotypic identification and technological properties of lactic acid bacteria isolated from traditionally processed fish products of the Eastern Himalayas. *Int. J. Food Microbiol.* 107, 33–38. doi: 10.1016/j.ijfoodmicro.2005.08.009

Thapa, N., Pal, J., and Tamang, J. P. (2007). Microbiological profile of dried fish products of Assam. *Indian J. Fisheries* 54, 121–125.

Thapa, S., and Tamang, J. P. (2004). Product characterization of kodo ko jaanr: fermented finger millet beverage of the Himalayas. *Food Microbiol.* 21, 617–622. doi: 10.1016/j.fm.2004.01.004

Thapa, S., and Tamang, J. P. (2006). Microbiological and physico-chemical changes during fermentation of kodo ko jaanr, a traditional alcoholic beverage of the Darjeeling hills and Sikkim. *Indian J. Microbiol.* 46, 333–341.

Toldra, F. (2007). *Handbook of Fermented Meat and Poultry. Oxford: Blackwell Publishing.* doi: 10.1002/9780470376430

Tou, E. H., Mouquet-River, C., Rochette, I., Traoré, A. S., Treche, S., and Guyot, J. P. (2007). Effect of different process combinations on the fermentation kinetics, microflora and energy density of *ben-saalga*, a fermented gruel from Burkina Faso. *Food Chem.* 100, 935–943. doi: 10.1016/j.foodchem.2005.11.007

Tsuyoshi, N., Fudou, R., Yamanaka, S., Kozaki, M., Tamang, N., Thapa, S., et al. (2005). Identification of yeast strains isolated from marcha in Sikkim, a microbial starter for amylolytic fermentation. *Int. J. Food Microbiol.* 99, 135–146. doi: 10.1016/j.ijfoodmicro.2004.08.011

Urushibata, Y., Tokuyama, S., and Tahara, Y. (2002). Characterization of the *Bacillus subtilisyws C* gene, involved in ⌊–polyglutamic acid production. *J. Bacteriol.* 184, 337–343. doi: 10.1128/JB.184.2.337-343.2002

Vallejo, J. A., Miranda, P., Flores-Félix, J. D., Sánchez-Juanes, F., Ageitos, J. M., González-Buitrago, J. M., et al. (2013). Atypical yeasts identified as *Saccharomyces cerevisiae* by MALDI-TOF MS and gene sequencing are the main responsible of fermentation of *chicha*, a traditional beverage from Peru. *Syst. Appl. Microbiol.* 36, 560–564. doi: 10.1016/j.syapm.2013.09.002

van Hijum, S. A. F. T., Vaughan, E. E., and Vogel, R. F. (2013). Application of state-of-art sequencing technologies to indigenous food fermentations. *Curr. Opin. Biotechnol.* 24, 178–186. doi: 10.1016/j.copbio.2012.08.004

Vieira-Dalodé. G., Jespersen, L., Hounhouigan, J., Moller, P. L., Nago, C. M., and Jakobsen, M. (2007). Lated with *gowé* production from sorghum in Bénin. *J. Appl. Microbiol.* 103, 342–349. doi: 10.1111/j.1365-2672.2006.03252.x

Walker, G. M. (2014). "Microbiology of Winemaking," in *Encyclopaedia of Food Microbiology, 2nd Edn*., eds C. Batt and M. A Tortorello (Oxford: Elsevier Ltd.), 787–792. doi: 10.1016/B978-0-12-384730-0.00356-6

Wang, C. T., Ji, B. P., Li, B., Nout, R., Li, P. L., Ji, H., et al. (2006). Purification and characterization of a fibrinolytic enzyme of *Bacillus subtilis* DC33, isolated from Chinese traditional *Douchi*. *Indus. Microbiol. Biotechnol.* 33, 750–758. doi: 10.1007/s10295-006-0111-6

Wang, J., and Fung, D. Y. C. (1996). Alkaline-fermented foods: a review with emphasis on pidan fermentation. *Crit. Rev. Microbiol.* 22, 101–138. doi: 10.3109/10408419609106457

Wang, J., Tang, H., Zhang, C., Zhao, Y., Derrien, M., Rocher, E., et al. (2015). Modulation of gut microbiota during probiotic-mediated attenuation of metabolic syndrome in high fat diet-fed mice. *ISME J.* 9, 1–15. doi: 10.1038/ismej.2014.99

Watanabe, K., Fujimoto, J., Sasamoto, M., Dugersuren, J., Tumursuh, T., and Demberel, S. (2008). Diversity of lactic acid bacteria and yeasts in airag and tarag, traditional fermented milk products from Mongolia. *World J. Microbiol. Biotechnol.* 24, 1313–1325. doi: 10.1007/s11274-007-9604-3

Watanabe, K., Fujimoto, J., Tomii, Y., Sasamoto, M., Makino, H., Kudo, Y., et al. (2009a). *Lactobacillus kisonensis* sp. *nov., Lactobacillus otakiensis sp. nov., Lactobacillus rapi sp. nov. and Lactobacillus sunkii sp. nov., heterofermentative species isolated from sunki, a traditional Japanese pickle. Int. J. Syst. Evol. Microbiol.* 59, 754–760. doi: 10.1099/ijs.0.004689-0

Watanabe, K., Makino, H., Sasamoto, M., Kudo, Y., Fujimoto, J., and Demberel, S. (2009b). *Bifidobacterium mongoliense* sp. *nov., from airag, a traditional fermented mare's milk product from Mongolia. Int. J. Syst. Evol. Microbiol.* 59, 1535–1540. doi: 10.1099/ijs.0.006247-0

Weckx, S., Meulen, van der., Maes, R., Scheirlinck, D., Huys, I., Vandamme, G. P., and De Vuyst, L. (2010). Lactic acid bacteria community dynamics and metabolite production of rye sourdough fermentations share characteristics of wheat and spelt sourdough fermentations. *Food Microbiol.* 27, 1000–1008. doi: 10.1016/j.fm.2010.06.005

Wei, D., and Jong, S. (1983). Chinese rice pudding fermentation: fungal flora of starter cultures and biochemical changes during fermentation. *J. Ferment. Technol.* 61, 573–579.

Winarno, F.G., Fardiaz, S., and Daulay, D. (1973). *Indonesian Fermented Foods.* Indonesia: Department of Agricultural Product Technology, Bogor Agricultural University.

Wongputtisin, P., Khanongnuch, C., Kongbuntad, W., Niamsup, P., Lumyong, S., and Sarkar, P. K. (2014). Use of *Bacillus subtilis* isolates from Tua-nao towards nutritional improvement of soya bean hull for monogastric feed application. *Lett. Appl. Microbiol.* 59, 328–333. doi: 10.1111/lam.12279

Wood, B. J. B. (1998). *Microbiology of Fermented Foods*. London: Blackie Academic Professional,

Wu, R., Wang, L., Wang, J., Li, H., Menghe, B., Wu, J., et al. (2009). Isolation and preliminary probiotic selection of lactobacilli from Koumiss in Inner Mongolia. *J. Basic Microbiol.* 49, 318–326. doi: 10.1002/jobm.200800047

Wu, Y. C., Kimura, B., and Fujii, T. (2000). Comparison of three culture methods for the identification of *Micrococcus* and *Staphylococcus* in fermented squid shiokara. *Fish. Sci.* 66, 142–146. doi: 10.1046/j.1444-2906.2000.00021.x

Yamamoto, S., and Matsumoto, T. (2011). Rice fermentation starters in Cambodia: cultural importance and traditional methods of production. *Southeast Asian Stud.* 49, 192–213.

Yan, P. M., Xue, W. T., Tan, S. S., Zhang, H., and Chang, X. H. (2008). Effect of inoculating lactic acid bacteria starter cultures on the nitrite concentration of fermenting Chinese paocai. *Food Control* 19, 50–55. doi: 10.1016/j.foodcont.2007.02.008

Yan, Y., Qian, Y., Ji, F., Chen, J., and Han, B. (2013). Microbial composition during Chinese soy sauce *koji*-making based on culture dependent and independent methods. *Food Microbiol.* 34, 189–195. doi: 10.1016/j.fm.2012.12.009

Yonzan, H., and Tamang, J. P. (2010). Microbiology and nutritional value of *selroti*, an ethnic fermented cereal food of the Himalayas. *Food Biotechnol.* 2, 227–247. doi: 10.1080/08905436.2010.507133

Yonzan, H., and Tamang, J. P. (2013). Optimization of traditional processing of *Selroti*, a popular cereal-based fermented food. *J. Sci. Indu. Res.* 72, 43–47.

Yoon, M. Y., Kim, Y. J., and Hwang, H. J. (2008). Properties and safety aspects of *Enterococcus faecium* strains isolated from *Chungkukjang*, a fermented soy product. *LWT Food Sci. Technol.* 41, 925–933. doi: 10.1016/j.lwt.2007.05.024

Yousif, N. M. K., Huch, M., Schuster, T., Cho, G. S., Dirar, H. A., Holzapfel, W. H., et al. (2010). Diversity of lactic acid bacteria from Hussuwa, a traditional African fermented sorghum food. *Food Microbiol.* 27, 757–768. doi: 10.1016/j.fm.2010.03.012

Yu, J., Wang, W. H., Menghe, B. L., Jiri, M. T., Wang, H. M., Liu, W. J., et al. (2011). Diversity of lactic acid bacteria associated with traditional fermented dairy products in Mongolia. *J. Dairy Sci.* 94, 3229–3241. doi: 10.3168/jds.2010-3727

Zhang, J. H., Tatsumi, E., Fan, J. F., and Li, L. T. (2007). Chemical components of *Aspergillus*-type Douchi, a Chinese traditional fermented soybean product, change during the fermentation process. *Int. J. Food Sci. Technol.* 42, 263–268. doi: 10.1111/j.1365-2621.2005.01150.x

Zhu, Y. P., Cheng, Y. Q., Wang, L. J., Fan, J. F., and Li, L. T. (2008). Enhanced antioxidative activity of Chinese traditionally fermented Okara (Meitauza) prepared with various microorganism. *Int. J. Food Prop.* 11, 519–529. doi: 10.1080/10942910701472813

Zhu, Y., and Trampe, J. (2013). Koji – where East meets West in fermentation. *Biotechnol. Advance* 31, 1448–1457. doi: 10.1016/j.biotechadv.2013.07.001

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.