Chapter 12
Novel Fermented Grain-Based Products

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12.1 Introduction

The process of natural fermentation is known earlier than 7000 BC and starts from China (for example, the making of koji, mould -fermented grains and/or soybeans, a source of more than 50 enzymes in has originated in China and was developed in Japan about 1000 years ago) going through different stages of improvement since that time through Georgia, Iran, Babylon, Egypt, Mexico, Sudan and other countries. Grain fermentation is one of the oldest known forms of food preparation, developed thousands of years ago by ancient man with use of one or a few strains of microorganisms to improve digestive and nutritional properties of grains and grains produced beverages (Wood, 1997). However, the deep mechanism of fermentation carried on with microorganisms was not understood and explained properly until about 200 years ago. The first fermented beer is known to be produced since over 7000 years ago in Syria, Mesopotamia and Caucasia and about 5000 years in Babylon, the fermented bread was known from Ancient Egypt and then around 100 BC in Ancient Rome.

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K.S. Ojha, B.K. Tiwari (eds.), *Novel Food Fermentation Technologies*,
Food Engineering Series, DOI 10.1007/978-3-319-42457-6_12

Food grains providing fibres, proteins, vitamins and minerals present over 60 % of the food world production (Charalampopoulos, Wang, Pandiella, & Webb, 2002). The grain components which are hard to digest and such compounds like phytates, tannins and polyphenols (Sindhu & Khetarpaul, 2001) could be broken down by the fermentation process using malt enzymes and microorganisms, especially lactic acid bacteria. This type of fermentation leads to a significant increase in amount of iron, zinc, calcium, vitamin B, essential amino acids, lysine and protein content and improvement of flavour and texture, while decreasing level of complex carbohydrates and mycotoxins (Lee, Lee, Park, Hwang, & Ji, 1999; Nout & Ngoddy, 1997; Yousif & El Tinay, 2000). Sourdough fermentation protects bread from mould and bacterial spoilage, which are especially important in warm natural environment (Corsetti et al., 2000; Rosenquist & Hansen, 1998). Spoilage of sourdough-baked products by mould genera including *Penicillium, Aspergillus, Monilia, Mucor, Endomyces, Cladosporium, Fusarium,* and *Rhizopus* causes a huge economic concern (Legan, 1993). Sourdough fermentation starters produce lactic acid, acetic acid, ethanol, hydrogen peroxide, carbon dioxide and other substances with antifungal properties (De Vuyst & Vandamme, 1994). The fermented grains-based products might have a pleasant appetizing aroma formed by the acetic acid, butyric acid and diacetyl (Blandino, Al-Aseeri, Pandiella, Cantero, & Webb, 2003), and significantly improved digestibility. Grains embryo contain fibre, carbohydrates, proteins, vitamins, sodium, magnesium, calcium, lipids and minerals, and bran layers are rich in proteins, niacin, phytic acid and phosphorus, oligosaccharides and is an excellent source of amino acids for grain fermentations by microorganism. The natural peptides derived by chemical or enzymatic fermentation are reported to possess various beneficial properties including antimicrobial, cholesterol-lowering, antithrombotic, antioxidant properties and cyto- or immunomodulatory effects (Coda, Rizzello, Pinto, & Gobbetti, 2012; Zambrowicz, Timmer, Polanowski, Lubec, & Trziszka, 2013). Fermentation of grains not only improve the yield, but also significantly change the profile of phenolic compounds leading to forming new metabolites through glycosylation, deglycosylation, methylation and glucuronidation, depending on the microbial strains and substrates. These phenolic compounds have antioxidative, anticarcinogenic and anti-inflammatory properties which have potential health benefits for hypertension, obesity, cardiovascular diseases, diabetes and cancer (Celep, Rastmanesh, & Marotta, 2014).

12.2 Grain-Based Fermented Foods and Beverages

There is a wide variety of grain-based fermented products produced by different cultures and in different countries all over the world, using combination of raw or processed grains and other nutritious and tasty ingredients. Among many of them are not only a bread, but also: *koji, tarhana, murri, togwa, ogi, boza, yosa, idli* and *dhokla, sake* and others, which can be classified according to natural substrate used for the fermentation process (Fig. 12.1).

Fig. 12.1 The variety of fermented foods produced internationally using different main substrates: rice, maize, wheat and millet (Copyright @ Dr. M. Emerald, 2016)

Koji (kōji) in Japanese (which is also called ‘qu’ in Chinese and ‘nurukgyun’ in Korean), which is first mentioned in 300 BC, is a special traditional national culture made by growing different fungi on cooked grains (Shurtleff & Aoyagi, 2013). The amylases, proteases, lipases and tanninase, bioactive enzymes produced by koji moulds hydrolyzing starches, proteins and fats into glucose, peptides, amino acids and fatty acid. The main fungi used in koji production are *Aspergillus oryzae*, *Aspergillus sojae*, *Aspergillus usami*, *Aspergillus awamori*, *Aspergillus kawachii,* *Rhizopus* spp. and *Monascus* spp. Chinese 'qu' fermentations involving different substrates rice, wheat, barley, soybeans and others, as well as fungi genera of *Aspergillus* spp., *Rhizopus* spp., *Monascus* spp., *Mucor* spp. and *Absidia* spp.

Tarhana is Turkish fermented for several (1–7) days at 30 °C with pH 4.3–4.8 mixture which is produced from white wheat flour, yogurt, onions, tomato puree, yeast (baker's yeast), salt, paprika, dill, mint, tarhana otu (*Echinophora sibthorpiana*) and water (Ibanoglu, Ainsworth, Wilson, & Hayes, 1995). The starter culture contains *Streptococcus thermophilus* and *Lactobacillus bulgaricus* (Economidou & Steinkraus, 1993). Tarhana is a good source of protein and vitamins and has a sour taste.

Murri is originated in Byzantine, and barley-based represent wrapping of raw barley dough in fig leaves which are left to sit for 40 days with following addition raisins, carob, dill, fennel, nigella, sesame, anise, citron leaf and pine seed.

Togwa produced in Tanzania is fermented beverage prepared from maize, sorghum, millet or cassava. The fermentation could be spontaneous or using *Lactobacillus brevis, Lactobacillus cellobiosus, Lactobacillus fermentum, Lactobacillus plantarum, Pediococcus pentosaceus* and yeasts (*Candida pellicu-losa, Candida tropicalis* and *Saccharomyces cerevisiae*) for 9–24 h and pH ≤ 3.8 (Mugula, Nnko, Narvhus, & Sørhaug, 2003).

Ogi is naturally fermented product typical for West Africa and could be named such as eko, agidi, kamu, akamu, koko and furah depending on the substrate used. It is produced by lactic acid fermentation of corn, sorghum or millet with occasional addition of soy beans, using *Lactobacillus plantarum*, *Corynebacterium*, *Saccharomyces cerevisiae* and *Candida* spp., by pH 3.6–3.7 (Blandino et al., 2003). Ogi is rich in phosphorous, niacin and riboflavin (Kuboye, 1985).

Boza (which means millet in Farsi language, and known since fourth century BC) is viscous fermented millet, corn, barley, rye, oats or wheat drink. To produce boza, millet is crushed into semolina size pieces and boiled with following addition of water, sugar and starter yeast. After 24 h fermentation at 30 °C, boza is cooled and settled at about 4–5 °C and is ready to be served. This drink contains proteins, carbohydrates, fat and various vitamins; it is high in lactic acid which has stimulating effects on digestion and to the intestinal flora (Arıcı & Turan, 2007).

Yosa is Scandinavian oat bran pudding cooked in water and fermented with lactic acid and Bifidobacteria and flavoured with sucrose, fructose and jam. It is great source of β-glucan, which can reduce the risk of heart disease (Blandino et al., 2003). The starter lactic acid bacteria may belong to the species *Lactobacillus acidophilus*, *Lactobacillus rhamnosus*, *Lactobacillus plantarum*, *Lactobacillus paraplantarum*, *Lactobacillus fermentum*, *Lactobacillus casei*, *Lactobacillus paracasei* and *Lactobacillus salivarius*. Bifidobacteria used are *Bifidobacterium lactis*, *Bifidobacterium longum* and *Bifidobacterium bifidum*.

Idli and Dhokla are a very viscous suspension (batter) made of a blend of rice (*Oryza sativa*) and *Phaseolus mungo*, or other substrate and popular in India and Sri Lanka (Sands & Hankin, 1974). The fermentation is stimulated by *Leuconostoc mesenteroides*, *Streptococcus faecalis*, *Lactobacillus delbrueckii*, *Lactobacillus fermenti*, *Lactobacillus lactis*, and *Pediococcus cerevisiae*, *Lactobacillus mesenteroides*, yeasts *Geotrichum candidum*, *Torulopsis holmii*, *Torulopsis candida* and

Trichosporon pullulans (Chavan & Kadam, 1989). Fermentation increases amino acids and reduces antinutrients (such as phytic acid), enzyme inhibitors and flatus sugars content (Steinkraus, 1983).

12.3 Grain Sourdough and Bread

Sourdough is a mixture of flour and water fermented with lactic acid bacteria and yeasts and first sourdough preparation is known over 5000 years. A huge variety of sourdough products are commercially available (Vogel & Gänzle, 2009). There are many factors which are important for proper sourdough production, such as chemical composition of the raw materials, interactions between the microorganisms, length of fermentation, temperature, dough yield and others. The sourdough fermentation occurs due to its microflora, basically represented by lactic acid bacteria and yeasts (Corsetti & Settanni, 2007). The complex mechanism of sourdough is dependent on the flour used and sourdough microflora. Typical microflora for what bread sourdough is *Lactobacillus*, *Pediococcus, Enterococcus, Lactococcus* and *Leuconostoc*, and *Lactobacillus sanfranciscensis*, *Lactobacillus brevis* and *Lactobacillus plantarum* are the most frequent lactobacilli isolated from sourdoughs (Corsetti, Settanni, Valmorri, Mastrangelo, & Suzzi, 2007; De Vuyst & Vancanneyt, 2007; Hammes & Gänzle, 1998). There are two groups of lactobacillus which are used for food fermentation purposes: homofermentative and heterofermentative. Homofermentative lactobacillus species used in a majority fermented foods for acidification and flavour, which do not produce any carbon dioxide. Heterofermentative lactobacillus species play crucial role in sourdough fermentation, improve taste and flavour of the sourdough breads. Sourdough's with *Saccharomyces cerevisiae* have great stability and resulted in high-profile volatile compounds. There is significant difference between Lactobacillus strains used for production of different sourdough from different regions of the world. Lactic acid bacteria found in Greek traditional wheat sourdoughs produced without yeast, include *Lactobacillus sanfranciscensis*, *Lactobacillus brevis, Lactobacillus paralimentarius* and *Weissella cibaria.* Heterofermentative *Lactobacillus alimentarius* strains are typical for Japanese bread, and *Lactobacillus brevis* and *plantarum* with *Lactobacillus fermentum* found in Russian sourdoughs. Belgian sourdough characterized by *Lactobacillus paralimentarius*, *Lactobacillus sanfranciscensis*, *Lactobacillus plantarum* and/or *Lactobacillus pontis* (Scheirlinck et al., 2007; Murooka & Yamshita, 2008).

According to the production technology and microorganisms, sourdough can be grouped into a three basic types (Fig. 12.2). Type 1, contains pure culture with stable composition, high souring activity and resistant against microbial contamination, which can produce large amounts of lactic acid and acetic acid from maltose (Corsetti, Gobbetti, Rossi, & Damiani, 1998; Damiani et al., 1996). In sourdough, maltose is the most present fermentable carbohydrate, and its catabolism is a key for the proper fermentation process. Sourdough type

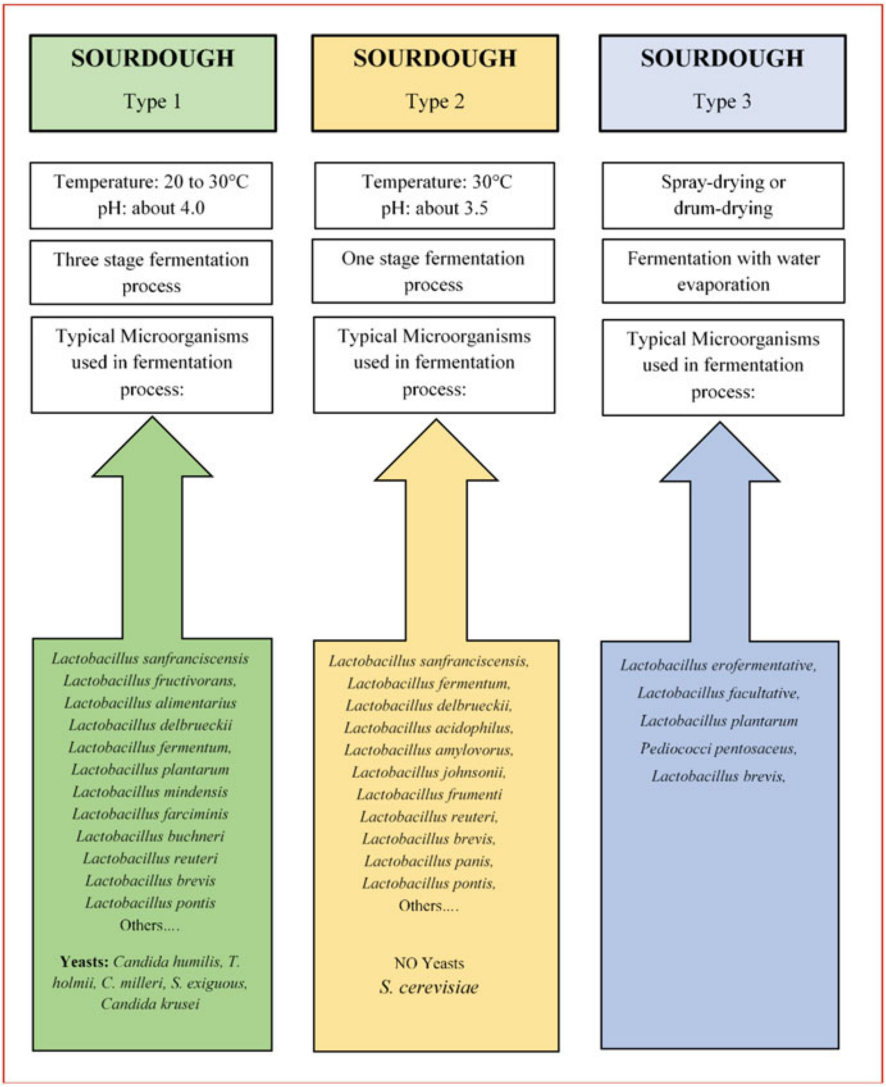

Fig. 12.2 Main types of sourdough and its typical microflora (Copyright @ Dr. M. Emerald, 2016)

2 using one-step fermentation which is common now and typical for industrial a large-scale production. This type guarantees more production reliability and flexibility, the microorganisms used have restricted metabolic activity only and are stored fresh up to 1 week (Stolz & Bocker, 1996). Type 3 sourdoughs are initiated by starter cultures available in dry form and mostly contain *Lactobacillus* spp. which are resistant to drying, which is quite simple to use: *Lactobacillus brevis*, *P. pentosaceus* and *Lactobacillus plantarum* strains.

Recently developed commercial dried prepared starter cultures (single- and multiple-strain cultures) consist of *Lactobacillus fructivorans* or *Lactobacillus brevis*, *Lactobacillus pontis*, *Lactobacillus plantarum*, *Lactobacillus delbrueckii* and *Lactobacillus sanfranciscensis* and are quite efficient for the industrial sourdough production (Hamad, Böcker, Vogel, & Hammes, 1992). Powerful antifungal potential of the *Lactobacillus* spp. strains against inhibit *Aspergillus, Fusarium* and *Penicillium*, due to the lactic, acetic and phenyllactic acids, and two cyclic dipeptides (L-Leu–L-Pro and L-Phe–trans-4-OH-L-Pro) have been reported (Gerez, Torino, Rollán, & De Valdez, 2009; Lavermicocca, Valerio, & Visconti, 2003). Combination of *Lactobacillus diolivorans* with *Lactobacillus buchneri* which produced propionate from lactate during sourdough fermentation, as well as addition of powerful antifungal extracts caused significant inhibition of moulds growth for more than 12 days (Coda et al., 2008). However, the application of antifungal *Lactobacillus* spp. cultures in baked products is still limited in spite of their effectiveness.

A variety of yeasts including *Candida milleri*, *Candida holmii*, *Saccharomyces exiguous, Pichia anomala, Hansenula anomala, Saturnispora saitoi, Pichia saitoi, Torulaspora delbrueckii, Debaryomyces hansenii, Pichia membranifaciens* and others, which usually produce metabolites such as alcohols, esters, carbonyl and others, compounds and contribute to leavening, were isolated from sourdough. The type of the yeasts which are active in sourdough formula is dependent on the grain material used, dough hydration, temperature of dough mix, pH, acetic and lactic acid concentration (Gänzle, Häusle, & Hammes, 1997). The bread properties, such as flavour, firmness, crust colour and stickiness, are dependent on the yeast's enzymatic activity caused by proteases, lipases, α-glucosidase, β-fructosidase and other vital enzymes. The bread flavour is composed of volatile and non-volatile compounds, produced both in lactic acid fermentation and in alcoholic fermentation, such as alcohols, ketones, aldehydes, acids, esters, hydrocarbons, ketones, pyrazines, lactones, ethers derivatives and sulphur compounds. Variety of grains and products obtained using the fermentation technologies are powerhouse of phytonutrients and bioactive ingredients which possess significant health benefits. They are rich in vitamins, minerals, dietary fibre, β-glucan, insulin, phytosterols and sphingolipids (Okarter & Liu, 2010) which are crucial for balanced nutrition and human health. Whole-grain phenolic compounds which found in free and soluble forms in corn, wheat, rice, oats, such as phytosterols, ferulic acid, p-coumaric acid, anthocyanidins, quinines, flavonols, chalones, flavones, flavanones, amino phenolic compounds (Adom, Sorrells, & Liu, 2005), usually released via thermal processing and milling provide various health benefits (Chatenoud et al., 1998; Okarter & Liu, 2010). Grains used for bread making also contain lutein, zeaxanthin, β-cryptoxanthin, β-carotene, α-carotene, tocotrienols, tocopherols, oryzanol, unsaturated fatty acids, linoleic acid, oligosaccharides and lignans, which all have important therapeutic properties.

12.4 Grain Brewing

Brewing has been in practice since the beginning of human civilization and nowadays is enjoyed by every ethnic society in the world. Beer is considered the fifth most consumed beverage with an average consumption of 9.6 L/capita (OECD, 2005). The brewing sector holds a strategic economic position which generated a total global revenue of US $318.4 billion in 2014 and is expected to garner US $688.4 billion with 6 % CAGR by 2020 (FAO Source, 2003; Research & Markets Report, 2015). Though the name 'beer' has ambiguity as some people refer it to 'a grain-based fermented beverage', whereas others explain it as a 'hopped drink prepared from liquefied starch after fermentation with specific yeasts' (Meussdoerffer, 2009). The brewing process utilizes barley, wheat or other malted grains along with the adjuncts (unmalted sugar, corn syrups, etc.) and specific strains of *Saccharomyces* yeast to produce beer (Olajire, 2012). The low water activity of stored grains keeps them in metabolically resting state, and therefore, grain constituents are not available for microorganisms, the endogenous enzymes are inactive because of low moisture content and endogenous hydrolytic activities do not take place at this stage. During malting and brewing stage, the water activity of grains increases which continuously change the ecological state of the cereal matrix (Hammes et al., 2005). Though these stages are certainly affected by various characteristic variables which vary from grain to grain and it is necessary to control these basics to get a defined quality product. These variables include the grain type, its nutrients profile and growth factors such as vitamins, minerals and microbial growth inhibiting substance (Hammes & Gänzle, 1998). Among these variables, the type of grain and its carbohydrate contents plays a key role because carbohydrates are a primary substrates and its amount and quality is very important for fermentation (Hammes et al., 2005). After these stages, the substrate becomes available for microorganisms to carry out the fermentation process.

Among all the grains, barley is considered the basic raw material for brewing. It is rich in carbohydrate, protein, dietary fibres, vitamins and minerals. Whole barley grain consists of about 65–68 % starch, 10–17 % protein, 4–9 % β-glucan, 2–3 % free lipids, 1.5–2.5 % minerals, 11–34 % total dietary fibres and from 3 to 20 % soluble dietary fibres of its total mass (Fastnaught, 2001; Gupta, Abu-Ghannam, & Gallaghar, 2010; Quinde, Ullrich, & Baik, 2004). The other non-starch, mixed linkage (1–3 and 1–4) D-glucans and arabinoxylans polysaccharides along with the enzymes help in barley modification for brewing (Gupta et al., 2010). Barley is climatically highly adaptable cereal grain that is produced all over the globe including East and Southeast Asia, the Middle East, North Africa, Northern and Eastern Europe (Newman & Newman, 2006). Figure 12.3 explains the whole brewing process utilizing barley which starts from malting step wherein selected grain goes into an incomplete natural germination process which involves a series of enzymatic degradation and releases the starch from endosperm matrix. This series of structural and biochemical degradation referred to as endosperm modification (Gunkel, Voetz, & Rath, 2002). The malting, comprises steeping, ger-

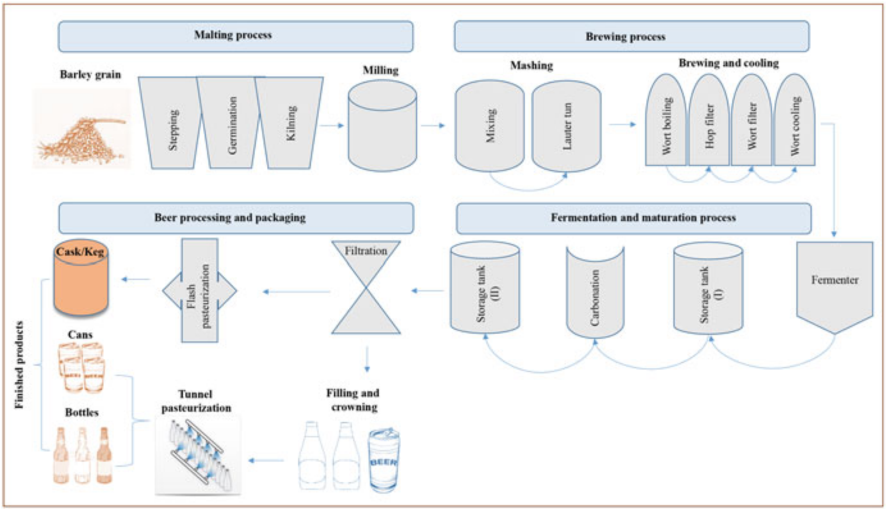

Fig. 12.3 The process of beer production from barley grain

mination and kilning, is a controlled process which ensures the final brewed product quality and stability. Endosperm structure, starch content, starch granule size and distribution, protein content, cell wall properties and endogenous enzymes are few factors that affect the whole malting process (Ogushi et al., 2002). After this step, the enzymatic activity and soluble protein content is increased and more simple sugars are freely available which change the typical colour and flavour of the product (Hoseney, 1994). After completion of milling, the malted grain is transferred to the brew house for mashing which is first but a key step of brewing process. During mashing, the enzymatic degradation of malt takes place and a mixture of milled malt, gelatinized adjunct and water called 'mash' is produced. Furthermore, the starchy content of the mash is hydrolyzed through a series of mixing, heating and cooling process, and a liquid called sweet wort is produced. This step ensures to obtain high yield of sweet wort and also safeguards the end products uniformity (Olajire, 2012). Once the wort is cooled, it is inoculated and mixed with yeast under the influence of oxygen and transferred into the fermenter vessel. The fermenter vessels come in all sizes, big and small ranging from 20 barrel (24 hectolitres) to as large as 6000 barrel (7200 hectolitres) tank depending upon the size of breweries (Gribbins, 2013). During fermentation process, the yeast metabolized the fermentable sugars in the sweet wort and converted it into alcohol (Gupta et al., 2010; Olajire, 2012). In this step, a series of chemical and enzymatic reaction takes place inside the brewing yeast cell which utilizes different sugars (glucose, fructose, sucrose, maltose and maltotriose) depending upon the type of malted grains. The carbon dioxide (CO_2) is also produced during the fermentation step which can be recovered and reused later. Fermentation process time varies from a few days to closer to 10 days and the rate of fermentation depends upon type of the yeast strain, taste profile and other fermentation parameters. After the completion of fermentation step, yeast is removed from the vessel and the product is stored in an aging tank. The carbon dioxide produced at this stage is dissolved in the beer and carryout the carbonation process. Beer aging or maturation is the last step wherein the beer is cooled and stored. The settled yeast and other precipitants is removed and the beer is held at conditioning temperature (−1 to 10 °C) for several days to over a month for maturation and stabilization. Finally, the beer is dosed with hop extracts and flavour additives, pasteurized to remove harmful microorganisms and filtered with various types of filters (Olajire, 2012). The filtered beer is then packed into the bottles, can or keg and transported to the pubs/super markets.

The brewing is an energy intensive process and uses large volumes of water, especially in the brew house, where mashing and wort boiling take place (Olajire, 2012). Antioxidant compounds from malted grain or incorporated hop extracts improve the beer flavour stability. The availability of high level of phenolic compounds in malted grains seems very important to produce nutritionally healthier beer with high levels of antioxidant activity (Maillard, Soum, Boivin, & Berset, 1996). Despite the types of grain, the taste of the beer depends upon the whole brewing process including biochemical and microbiological changes that occur during malting, fermentation and subsequent processing and storage throughout the production. For instance, compared to the Western-type beer, traditional African beer tastes more saury, less carbonated and contains no hops. They are usually consumed unrefined which includes unfermented substrates and microorganisms (Blandino et al., 2003; Haggblade & Holzapfel, 1989, 1993).

Though beer is one of the most commonly consumed beverages but, the consumption of conventional grain (barley, wheat and rye)-based beer is not safe for coeliac or gluten-intolerant people (Hager, Taylor, Waters, & Arendt, 2014). In the modern brewing process, the gluten protein and coeliac toxic polypeptides are removed via polyvinylpolypyrrolidone (PVPP) and silica gel filtration process and a very small percentage of total protein/peptides (0.2–0.6 %) remains in beer (Dostalek, Hochel, Mendez, Hernando, & Gabrovska, 2006; Picariello et al., 2011). Nevertheless, very small amount of gluten or coeliac toxic peptide in beer is enough for the immunotoxicity. Therefore, rice, corn, sorghum, millet and pseudocereals (quinoa, buckwheat and amaranth) are considered safe for gluten free beer production (Hager et al., 2014). Apart from health issues, people in Africa and Asia utilize other grains for brewing to get the different taste and flavour. In Africa, malted or germinated single cereal grains or a mixture of them is typically used in *Pito* and *Burukutu* brewing, whereas *Ajon*, *Omuramba* and *Kweete* brewery products are prepared from finger millet, sorghum and a mixture of maize and millet, respectively (Iwuoha & Eke, 1996; Mwesigye & Okurut, 1995). Furthermore, rice-based fermented brewery products such as *Makgeolli*, *Mijiu*, *Pangasi*, *Raksi*, *Rượu cần*, *Sake*, *Sato*, *Shaoxing*, *Sombai*, *Sonti*, *Tapai*, *Takju*, *Tapuy*, *Brem*, *Tuak*, *Ara*, *Cheongju*, *Cholai*, *Choujiu*, *Huangjiu*, *Hariya* and *Lao-Lao* are very popular in East and Southeast Asian countries (Banigo & Muller, 1972; Sankaran, 1998; Steinkraus, 1998; Svanberg & Sandberg, 1988).

12.5 Grain-Based Fermentation: Global Trends and Frontiers

According to the UN Food and Agriculture Organization, over 795 million people (majority is from the developing countries) are suffering from malnourishment and hunger in 2014–2016. In 2000, world leaders set out the Millennium Development Goals (MDGs) reflecting the world's commitment to improve the lives of people and beat the hunger. The term undernourishment defines insufficient food intake as the consumption of less than 1600–2000 calories per day. Sub-Saharan Africa represents about 58 % of the total food-insecure population (Rosen, Meade, Fuglie, & Rada, 2014). Taking into consideration that grains cultivation and harvesting are the main focus in many regions of the world, there is a strong trend on towards development of new nutritious and effective human and animal feeding products, especially fermented foods. Fermentation of grains transforms the flavour of food, its digestibility, shelf-life, texture and taste, adding beneficial bacteria and enhanced micronutrients which are crucial for human and animal health and proper nutrition. Fermented food in general, and fermented grains-based products have earned a great international reputation for the beneficial effects on immunity, which is especially important not only for the developing countries, but also for the intestinal health and general well-being. Lactic acid fermentation increases production of amino acids, especially lysine, which has powerful antiviral properties. It is especially important for the regions of the world where medical help is rarely available and where population is suffering from many rare and contagious diseases. Grains fermentation is crucial for reduction of phytic acid, non-nutrient which is typical for the unprocessed grains, and which binds up minerals and preventing their full absorption. The lactic acid fermentation enables better mineral absorption from the grains and results in better quality of food. A variety of bread produced from sourdough using different microorganisms and yeasts is an important solution which can help eliminate the hunger and nutritional deficiencies. Making fermented porridges from the grains is very popular in Africa and is the best available food for babies. Malted grains are rich in enzymes (amylase) that digests the starch into sugars which dissolve in the water. Fermentation makes the food more nutritious, and there are quite few new substrates which can be discovered and used, such as quinoa, buckwheat, chia and others. The traditional grains fermentation can reduce mycotoxin transfer from grains to fermented foods and increases food nutritional profile via synthesis of protein, vitamins and amino acids. There is much more research need to be done to understand further and discover the result of the bacterial diversity during grains fermentation, and to determine the precise mechanism of the mycotoxin reduction due to the fermentation process.

Countries all over the globe support production and use of biofuels produced via complex fermentation process from the grain products and animal feeds by-products, which will be leading to the domestic energy source, economic development and reduction of the emissions of greenhouse gases. The two primary biofuels produced globally today (ethanol and biodiesel) are derived from grain, sugar and oilseeds, and use of certain feedstocks for biofuels production also results in the co-production of animal feed. Biofuel production can be increased via increasing crop yields, and availability of the grain substrate for the ongoing manufacturing. One of the problems is the lack of quality measurements for the nutrient characteristics in distiller's grains. Distillers grains produced at different plants vary in texture, colour and nutritional profile, and quality. The attractiveness of the grains fermentation-based industry depends on the price levels of the functional molecules and the yield of fermentation processes. Development of crops for biomaterials, biochemicals and nutraceuticals is very important for economical growth and our society, and there is a lot of research and further development needs to be done in order to produce spoilage-resistant bread, better nutritional quality food and beverages, as well as clean ethanol and more affordable and efficient biofuel.

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