

# Cereal Based Beverages and Fermented Foods: A Review

Suman Kumari, Priti Guleria, Nidhi Dangi

Department of Food Technology, Maharshi Dayanand University, Rohtak (Haryana)-124001

---

## *Abstract*

Fermented foods and beverages play a significant role in most societies and major contribution in fulfil the protein requirements of large population. There is a relation between microbial diversity of food products and health benefits. Cereals are most important sources of dietary proteins, carbohydrates, vitamins, minerals and fibre for people all over the world. Fermented foods have been with us since humans arrived on earth. They will be with us far into the future as they are the source of alcoholic foods/beverages, vinegar, pickled vegetables, sausages, cheeses, yogurts, vegetable protein amino acid/peptide sauces and pastes with meat-like flavours, and leavened and sour-dough breads. Fermentation improves the shelf life, texture, taste and aroma, nutritional value and digestibility and also lowers the content of antinutrients of cereal products. All consumers today have a considerable portion of their nutritional needs met through fermented foods and beverages. There is a need to encourage researches in the area of cereal-based fermented foods in direction of more mechanistic approaches.

**Keywords:** Cereals, Fermented foods, Idli, Microorganisms.

---

## **Introduction**

Modern food processing is dependent on a range of preservative technologies to ensure that food is maintained at an acceptable level of quality from the time of manufacture through to the time of consumption. Fermentation has been used for preserving foods for centuries prior to the invention of pasteurization and sterilization. Every culture has a variety of fermented products as part of its diet. Fermentation in food processing is the conversion of carbohydrates to alcohols and carbon dioxide or organic acids using, bacteria and yeast or a combination of there, under anaerobic conditions. In fermentation action of microorganisms is desirable. The science of fermentation is also known as zymology. Since ancient times, however, humans have been controlling the fermentation process. The earliest evidence of a fermented alcoholic beverage, made from rice, fruit, and honey, in the Neolithic Chinese village of Jiahu, dates from 7000–6600 BC (McGovern *et al.*, 2004). Fermentation process dependent on the biological activity of microorganisms for production of metabolites which can suppress the growth and survival of undesirable microflora in food products (Ross *et al.*, 2002). Fermentation may be useful technique for reducing bacterial contamination of food and could also help to reduce the prevalence of diarrheal diseases (Mensah *et al.*, 1990). Fermentation is the most economical technique in which microorganisms play an essential role in food production and preservation. In addition, fermentation provides a natural way to reduce the volume of the material to be transported (Egounley, 2002). Food fermentation is one of the oldest biotechnology processes which play an important role in enrichment and improvement of food through enhancement of flavour, aroma, protein, essential amino acid and vitamins and change in texture, preservation of food through acetic acid, lactic acid, alcoholic and alkaline fermentation, detoxifying foods and reduce the cooking time. During traditional fermentation substrates which may be of plant or animal origin, are converted into edible products by the physiological activities of microorganisms. Fermented foods are strongly linked to the culture and tradition. Different kind of fermented foods have been prepared and consumed for thousands of years and these foods are better than normal cooked foods in terms of nutrition and digestibility (Steinkraus, 1996). Different foods can be produced by fermentation of cereals, legumes, tubers, vegetables, fruits, milk, meat and fish.

**Table 1.** Type of fermented food, starter culture and raw material used (Kohajdova & Karovicova, 2007)

Product Name	Raw materials used	Starter culture
Beer	Cereals	Yeast
Soya sauce	Soyabeans	Moulds ( <i>Aspergillus</i> ), Lactic acid bacteria
Bread	Grains	Yeast, Lactic acid bacteria
Wine	Grapes	Yeast, Lactic acid bacteria
Fermented milk	Milk	Lactic acid bacteria
Cheese	Milk	Lactic acid bacteria
Sauerkraut	Cabbage	Lactic acid bacteria
Fermented Sausages	Meat	Lactic acid bacteria
Pickled vegetable	Olive, Cucumber	Lactic acid bacteria
Gyagawere, Adjuevan	Catfish, Croaker, Meagre, Shark, Mullet	Lactic acid bacteria
Alcoholic beverage	Mahua flower	Yeast
Ogol	Honey	Yeast
Mead	Honey	Yeast

Fermentation of cereal based foods is a common practice all over the world. There are different types of cereal-based fermented beverages produced all around the world, which are classified on the basis of the raw material or the type of fermentation involved in the manufacturing process (Blandino et al., 2003). Alcoholic fermented beverages can be classified into wines and beers, while the great majority of non-alcoholic fermentations are souring, mainly lactic acid fermentations (Chavan & Kadam, 1989; Fleet, 1998). Fermentation is a simple; home based technology and has fed large population. At present a variety of cereals based fermented foods and beverages are produced at house hold and semi industrial level and these foods are used as weaning food for infants and children and also for adults (Kalui *et al.*, 2008). Scientific investigation has shifted to research on the fermentation benefits (Kalui *et al.*, 2010). Researcher has revealed that fermentation processes have been discovered to produce active substances (Grajek *et al.*, 2005). Fermented foods contain bioactive substrates that prevent or inhibit the allergies and diseases (Vasiljevic and Shah, 2008).

**Table 2.** Various compounds formed during cereal fermentations (Kohajdova & Karovicova, 2007)

Organic acids		Alcohols	Aldehydes and ketones	Carbonyl compounds
Butyric	Heptanoic	Ethanol	Acetaldehyde	Furfural
Succinic	Isovaleric	<i>n</i> -propanol	Formaldehyde	Methional
Formic	Propionic	Isobutanol	Isovaleraldehyde	Glyoxal
Valeric	<i>n</i> -Butyric	Amyl alcohol	<i>n</i> -Valderaldehyde	3-Methyl butanal
Caproic	Isoburyric	Isoamyl alcohol	2-Methyl butanol	2-Methyl butanal
Lactic	Caprylic	2,3-Butandieol	<i>n</i> -Hexaldehyde	Hydroxymethyl furfural
Acetic	Isocaprilic	$\beta$ -Phenylethyl alcohol	Acetone	
Capric	Pleagronic		Propionaldehyde	
Pyruvic	Mevulinic		Isobutyraldehyde	
Palmitic	Myristic		Methyl ethyl ketone	
Crotonic	Hydrocinnamic		Butanone	
Itaconic	Benzyllic		Diacetyl	
Lauric			Acetoin	

### Role of Cereals in fermentation

Cereals are a major component of human food in all over the world. Nutritional experts have paid attention to cereal based foods from maize, wheat, rice, barley, oat, sorghum and millet sources. During storage grains are metabolically inactive with very low water activity and moisture content of about 9 - 12%. This low water activity and low moisture content prevents the growth of microorganisms and the enzymes are also inactive at this state. This is the resting stage of the grain. Addition of water to the grains makes them absorb water which ultimately stimulates the enzyme into action and growth of microorganisms. This process enables fermentation to start. This is followed by size reduction through milling and sometimes the use of specific microorganisms and enzyme actions (Achi *et al.*, 2015). Cereals have high content of soluble non-starch polysaccharides such as  $\beta$ -glucan which has a health promoting role. Clinical and epidemiological studies reported that  $\beta$ -glucan from oat and barley based products control cardio vascular disease in human beings (Beck *et al.*, 2010). Cereals also contain relatively high levels of minerals, vitamins, sterols and other growth factors that support microbial growth. Physiological compounds used in functional food systems are available in cereals. Charalampopoulos *et al.* (2002) found that in his study, cereals are good fermentable substrates for the growth of probiotic microorganisms. Some important factors of substrates that affect growth of probiotics include; Composition of cereal substrate, processing method, fermentation of substrates, productivity of starter culture, growth of organisms, sensory and nutritional properties of products. Cereals have many health benefits e.g. prevent cardiovascular diseases and cancer, reduces tumour, lowers blood pressure, controls cholesterol level and lowers the incidents of heart diseases, reduce the rate of fat absorption, delays gastric emptying and improve gastrointestinal health (Achi *et al.*, 2015).

### Microbiology of cereals based fermented foods

The most important group of microorganisms involved in natural fermentation of foods are the lactic acid bacteria (Jakobsen and Lei, 2004). Lactic acid bacteria which produce lactic acid during fermentation is predominant among the microorganisms (Holzapfel and Schilinger, 2002; Shah, 2007). Many researchers have study on the probiotic potentials of fermented foods (Grajek *et al.*, 2005, Reid 2008; Vasiljevic and Shah 2008). Lactic acid bacteria are important microbes that are used all over the world in a large variety of industrial food fermentations (Hugenholtz and Smid, 2002). Lactic acid bacteria are Gram positive, non-spore forming catalase negative cocci or rods that are anaerobic in nature (Wood and Holzapfel, 1995). Lactic acid bacteria are the dominant organisms that ferment cereals. The basic fermentation process involves the enzymatic activities of *Lactobacilli*, *Leuconostoc*, *Lactococcus*, *Pediococci*, yeasts and moulds (Mensah, 1997). The primary function of the microorganisms in food fermentation is to convert carbohydrates to desired metabolites such as alcohol, lactic acid, acetic acid or carbon dioxide (Ajanaku *et al.*, 2012). Acids formation during fermentation reduced the pH to 4 or less, thus inhibiting the growth of spoilage micro-organisms (Sanni, 1993). Microorganisms ferment and produce lactic acid as a major component (Steinkraus, 2002). They include the genus *Lactobacillus*, *Bifidobacterium*, *Lactococcus*, *Leuconostoc*, *Pediococcus*, some *Enterococcus* and some *Streptococcus*. Some yeast such as *Saccharomyces* and moulds such as *Penicillium*, *Aspergillus* and *Botrytis* also produce lactic acid in some amount (Wood and Holzapfel, 1995). Examples of *Lactobacillus spp.* involved in lactic acid bacteria fermentation of cereal based fermented foods include *L. plantarum*, *L. casei*, *L. sakei*, *L. acidophilus*, and *L. salivarius* among others (Achi, 2005; Kalui *et al.*, 2009). The lactic acid fermentations provide foods with variety of flavors, aromas, textures in addition to the foods being safe and having a long shelf-life. However, not all lactic acid bacteria are useful; some are involved in food spoilage due to action of proteinases and lipases that degrade proteins and lipids, respectively, producing by-products that cause off-flavours e.g. *Pediococcus damnosus* produce off-flavour in beer while *L. bifementans* and *L. alimentarius* are associated with spoilage of refrigerated and packaged foods (Kalui *et al.*, 2010). Lactic acid bacteria have many health benefits, including anticarcinogenic antimutagenic, hypocholesterolemic properties. It also improves gasterointestinal health and their fermented products can also enhance the integrity of gastric mucosa

Fermentation of cereals with pure yeast cultures has been shown to increase the protein content of the fermented products (Svanberg and Lorri, 1997). The possible function of yeasts in fermented foods and beverages are to ferment the carbohydrates and form alcohols, esters, organic acids, carbonyls, etc. Yeast stimulate the growth of lactic acid bacteria, inhibit production of mycotoxin, degrade cyanogenic glucosides, produce tissue degradind enzyme e.g. pectinase and cellulose. It has been suggested that the proliferation of yeasts in foods is favoured by the acidic environment created by

lactic acid bacteria while the growth of bacteria is stimulated by the presence of yeasts, which provide growth factors, such as vitamins and soluble nitrogen compounds (Jespersen, 2003). The fermentation processes is often initiated by mixed microbial population. The organisms are usually from the environment or from the previous reserved batch. During fermentation acidity of medium increase that eliminates or inactivate non-lactic acid microorganisms while others continue with the fermentation. Surviving lactic acid bacteria in the fermentation form a synergy with some yeast (Mbata *et al.*, 2009). In addition, mould species such as *Aspergillus*, *Penicillium*, *Fusarium* and *Cladosporium* may be involved. Other organisms are *Corynebacterium*, *Saccharomyces cerevisiae* and *Streptococcus*.

*Lactobacillus* species play a significant role in most of the fermented cereals (Sanni, 1993). Rice is fermented by *Lactobacillus bulgaricus* and *Streptococcus thermophilus* because of the lack of amylase in rice, which is essential for saccharification of rice starch (Lee *et al.*, 1999). Mixed culture of propionic bacteria and lactic acid bacteria can also be used along with conventional starters in rye sour dough fermentation. *Lactobacillus plantarum* and *Pediococcus* species in maize dough fermentation cause rapid acidification of inoculated dough (Kohajdova *et al.*, 2007).

**Table 3.** Cereals based fermented foods and beverages

<b>Products</b>	<b>Microorganisms</b>	<b>Substrates</b>	<b>Regions</b>
Ogi	<i>Lactobacillus plantarum</i> , <i>Lactobacillus fermentum</i> , <i>Lactobacillus spp.</i> , <i>Saccharomyces cerevisiae</i> , <i>Candida mycoderma</i>	Maize,Sorghum/ Millet	West Africa
Enjara	<i>Candida guillienmandi</i>	Sorghum	Ethiopia
Pito	<i>Geotrichum candidum</i> , <i>Lactobacillus</i> , <i>Candida</i>	Sorghum/Millet	Nigeria, Ghana
Fura	<i>Lactobacillus plantarum</i> , <i>Pedicoccus</i> , <i>Leuconostoc</i> , <i>Streptococcus</i> , <i>Enterococcus</i> , <i>Pichia anomala</i> ,	Maize/Sorghum	Nigeria
Sake	<i>Saccharomyces spp.</i>	Rice	Japan
Dosa	<i>Leuconostoc mesenteroides</i> , <i>Streptococcus faecalis</i> , <i>Torulopsis candida</i> , <i>T. pullulans</i>	Rice and Bengal gram	India
Idli	<i>Leuconostoc mesenteroides</i> , <i>Streptococcus faecalis</i> , <i>Torulopsis</i> , <i>Candida</i> , <i>Tricholporon pullulans</i>	Rice grits and Black gram	South India, Sri Lanka
Miso	<i>Aspergillus oryzae</i> , <i>Torulopsis etchellsii</i> , <i>Lactobacillus spp.</i>	Rice and Soya	Japan ,China

Tarhana	<i>Zygosaccharomyces rouxi</i> <i>Streptococcus thermophilus</i> <i>Lactobacillus bulgaricus</i>	Wheat flour	Turkey
Soya sauce	<i>Aspergillus oryzae</i>	Soyabean, Wheat	Japan, China & India
Masa Agria	<i>Lactobacillus spp.</i> , <i>L. Plantarum</i> , <i>L. Fermentum</i>	Maize, Rye	Africa
Bread	<i>Saccharomyces cerevisiae</i>	Barley, Wheat	Middle East, North Africa, Europe America, Australia Southren, Africa Tanzania
Togwa	<i>Lactobacillus fermentum</i> , <i>Pediococcus pentosaceus</i>	Sorghum, Millet, Maize	Finland
Yosa	<i>Bifidobacteria</i> <i>Leuconostoc mesenteroides</i> ,	Oat bran	
Dhokla	<i>Streptococcus faecalis</i> , <i>Torulopsis candida</i> , <i>T. pullulans</i>	Bengal gram and Rice	South India, Srilanka
Beer	<i>Saccharomyces spp.</i>	Cereals grains	All over world

### Cereal-based fermented foods

#### **Idli**

Idli is a traditional fermented food, prepared and consumed in South India and in many parts of Sri Lanka (Steinkrau, 1996). It is normally consume with chutney and sambar. *Idli* made up of a blend of rice and dehulled black gram. For Idli preparation rice and black gram are soaked in water and then the rice is coarsely ground and the black gram is finely ground. Then the rice and the black gram batters are mixed together in 2:1 ratio with addition of a little amount of salt and leave it for fermentation overnight at about 30°C. Finally, the fermented batter is steamed for 5-8 min in Idli (Nagaraju & Manohar, 2000). Lactic acid bacteria *Leuconostoc mesenteroides*, *Lactobacillus fermenti*, *Streptococcus faecalis*, *Lactobacillus delbrueckii*, *Lactobacillus lactis* and *Pediococcus cerevisiae* are the significant microorganisms responsible for Idli fermentation. Some yeast like *Torulopsis holmii*, *Geotrichum candidum*, and *Trichosporon pullulans* are also helps in idli fermentation. Idli is a low caloric food used as breakfast and snacks. Fermentation increase essential amino acid in Idli and decrease antinutritients (Blandino *et al.*, 2003). In *Idli* preparation, instead of rice, kodri, millet and soybean or green gram instead of black gram are also used (Steinkraus *et al.*, 1996).

#### **Dosa**

In Dosa preparation, wheat, bajra, maize or *kodri* instead of rice and sprouted peas, cowpea, field beans, soybeans or groundnut oilcake instead of black gram are also used. Dosa batter is similar to Idli batter but the dosa batter is thinner (Steinkraus *et al.*, 1996). A dosa better is prepared by grinding wet rice and wet black gram individually with water and the two suspensions are then mixed and allowed to undergo fermentation, usually for 8–20 h. After fermentation, the fermented Dosa batter is heated with little oil on hot pan as thin, semi soft to crisp pancake and eaten with chutney and *Sambar*

(Blandino *et al.*, 2003). The microbiological and nutritive value of Dosa are similar to Idli (Shortt, 1998). Lactic acid bacteria *Leuconostoc mesenteroides*, *Lactobacillus fermenti*, *Streptococcus faecalis*, *Lactobacillus delbrueckii*, *Lactobacillus lactis* and yeast *Torulopsis holmii*, *Geotrichum candidum* are responsible for Dosa fermentation.

### **Pito**

Pito is a fermented food prepared from Sorghum, Millet and Maize. It is popular in Ghana and Southern Nigeria. *Saccharomyces spp.* and Lactic acid bacteria play an important role in fermentation. It contains 3% alcohol content (Badmos *et al.*, 2014).

### **Soya sauce**

Soy sauce is a fermented dark brown liquid, made from a blend of soybeans and wheat. It is popular in Japan, China and used as seasoning (Yokotsuka, 1993). Soy sauces have a salty taste. For the preparation of soya sauce cooked soybeans are mixed with coarse wheat with initial moisture content 55%. The mixture is inoculated by molds, and after 3 days of fermentation mixture is called koji at this stage. Koji is mixed with 20-25% brine solution in 1:3 w/v. This brine solution containing koji is known as moromi. The moromi is left to ferment for a period of 1–12 months. After fermentation is completed, soy sauce is separated, filtered, pasteurised and bottled (Rowan *et al.*, 1998). The microorganisms involved in fermentation include fungi such as *Aspergillus oryzae* and *A. soyae* involved in the koji production, halotolerant lactic acid bacteria and yeast strains such as *Zygosaccharomyces rouxii* and *Candida* species responsible for the moromi fermentation (Blandino *et al.*, 2003). The characteristic aroma and flavour of Soy sauce is due to the enzymatic activities of yeasts and some lactic acid bacteria.

### **Yosa**

Yosa is a famous food in Finland and prepared from oat bran pudding cooked in water and fermented with lactic acid bacteria and *Bifidobacteria*. It is used as snack food and flavoured with fruit jam, sucrose or fructose. Oat fibre is a good source of  $\beta$  glucan, which can lower the cholesterol and reduce the risk of heart disease (Blandino *et al.*, 2003).

### **Dhokla**

Dhokla is cereals based fermented product. It is also similar to Idli except that Bengal gram dhal is used instead of black gram dhal in its preparation. It is famous in south India and Srilanka. A mixture of rice and chickpea flour is also used as the substrate for the fermentation. The fermented batter is poured into a greased pie tin and steamed in an open steamer as in Idli preparation (Ramakrishnan, 1993). As in other indigenous fermented foods, a significant improvement in the biological value and net protein utilisation of Dhokla due to fermentation has been reported. *Leuconostoc mesenteroides*, *Streptococcus faecalis*, *Torulopsis candida*, *T. pullulans* are the major microorganisms involved in Dhokla fermentation. It is used as steamed cake for breakfast or as snack food (Blandino *et al.*, 2003).

### **Ogi**

Ogi is made by lactic acid fermentation of corn but sorghum and millet are also added for fermentation. Sometimes soybeans may add to improve its nutritive value. It is considered a popular food for infant in West Africa although it is also consumed by adults (Blandino, 2003). For the preparation of Ogi, the cereal grains are steeped in earth ware or enamel pots for 1–3 days. Lactic acid bacteria, yeasts and moulds are responsible for the fermentation although *Lactobacillus plantarum* is the predominant microorganism. Other bacteria such as *Corynebacterium* and then yeasts of the *Saccharomyces cerevisiae* and *Candida* species also improve the flavour. Ogi is sour porridge with a flavour resembling yoghurt. (Blandino *et al.*, 2003). The colour of Ogi depends on the cereal grain used: cream-white for maize, reddish brown for sorghum, and grey for millet (Banigo, 1993). During the fermentation of Ogi phosphorous (Lopez *et al.*, 1983) riboflavin and niacin contents increase (Kuboye, 1985).

### **Bread**

Bread is one of the oldest prepared foods. Throughout recorded history it has been popular around the world and having importance since the dawn of agriculture. Bread has a social and emotional significance beyond its importance in nutrition; it plays essential roles in religious rituals and secular culture. It is prepared by baking from dough of flour and water. There

are many combinations and proportions of different kind of flour and other ingredients, and also of different traditional recipes and modes of preparation of bread. There are wide varieties of types, shapes, sizes, and textures of breads in various regions. Bread is the staple food of the Middle East, North Africa, Europe, and in European-derived cultures such as those in the Australia, Americas and Southern Africa. Bread is normally made from wheat flour and also with other cereal flours such as rye, oat barley and maize. Many types of bread are leavened by yeast. The most commonly yeast used for leavening bread is *Saccharomyces cerevisiae*. This yeast ferments some of the carbohydrates in the flour and produce carbon dioxide. Most bakers in the U.S. leaven their dough with commercially produced baker's yeast. Baker's yeast has the advantage of producing uniform, quick, and reliable results, because it is obtained from a pure culture. Pitas, White bread, Brown bread, Whole meal bread, Wheat germ bread, Roti are famous breads around the world.

Sourdough is an intermediate product between dough and traditional bread preparation, containing flour, water and metabolically active microorganisms, mainly lactic acid bacteria and yeast. During the fermentation of the dough, the metabolic products of lactic acid bacteria improve the organoleptic and technological properties of bread as well as their shelf life, nutritional value (Salovaara, 1988; Hammes *et al.*, 1998). The main genera of lactic acid bacteria isolated from sourdough are *Lactobacillus*, *Leuconostoc*, *Pediococcus* and *Weissella*, and the majority of the strains belong to the genus *Lactobacillus* (De Vuyst *et al.*, 2005)

### **Tarhana**

Tarhana is a wheat fermented product prepared by mixing wheat flour, sheep milk yoghurt, yeast and addition of cooked vegetables and spices followed by fermentation for 1–7 days (Campbell-Platt, 1994). Fermentation is carried out by *Streptococcus thermophilus* and *Lactobacillus bulgaricus* which are present in yoghurt of sheep milk (Economidou & Steinkraus, 1993) and stored in the form of biscuits. Tarhana is rich in protein and vitamin, acidic and sour in taste with a strong yeasty flavour. Tarhana can be used as soup and in breakfast (Blandino *et al.*, 2003).

### **Masa Agria**

Masa agria is a traditional maize fermented product can be either homemade or commercially produced. The conversion of maize into “*Masa agria*” involves a process in which maize pericarp is removed by peeling. The maize kernels are soaked in water and placed at 35–40°C temperature for 4 days so that fermentation can take place. After this maize is washed, milled and a dough is formed and allowed to stand for 3 or 5 days, during which a dehydration occurs and water activity decrease. A mixture of microorganisms carries out fermentation (Clemencia *et al.*, 2014). Lactic acid bacteria communities in the Masa agria samples are composed mainly of *Lactobacillus* species, in particular *L. Fermentum* and *L. plantarum* and (Gamboa *et al.*, 2009). After fermentation, the pH is reduced from 6.6 to 3.8. In this the enzymes e.g. amylases, proteases, phytases, and lipases are active and responsible for enhanced taste, aroma, texture, and increased stability at room temperature (Clemencia *et al.*, 2014). Moreover, fermentation of cereals increases protein quality, in particularly the lysine (Katongole 2008). During maize fermentation, the role of some microorganisms in aflatoxin detoxification has been reported. Higher reduction of mycotoxins aflatoxin B1 and zearalenone was observed in fermented maize products than in unfermented products (Mokoena *et al.*, 2005).

### **Injera**

Injera is made from different cereals, including finger millet, sorghum, tef, corn, and barley. It is an undisputed national food of Ethiopians (Chavan & Kadam, 1989) although tef is the major cereal in Ethiopian Injera. To prepare the *Injera* the grains are dehulled and milled into flour and dough is prepared by mixing water. The dough is fermented by adding previously saved starter for 2 or 3 days. After fermentation the dough is converting into a thick batter and the batter is poured in a tightly fitted oiled pan and then heat it for 2–3 minutes. After that remove it from pan and stored for 3 days at room temperature (Parker *et al.*, 1989). A typical Injera is round, slightly sour, spongy, soft, and about 6 mm thick, 60 cm in diameter with honeycomb-like “eyes” on the top (Gebrekidan & Gebrettiwat, 1982). The microorganisms involved in fermentation of Injera are mainly yeasts, some fungi including *Penicillium sp.*, *Pullaria sp.*, *Aspergillus sp.*, *Candida sp.*, *Rhodotorula sp.*, *Hormodendrum sp.*, and number of unidentified bacteria (Ashenafi, 1993). *Injera* is a rich in calcium and iron (Zegeye, 1997).

### Cereal-based fermented beverages

#### **Togwa**

Togawa is a fermented gruel or beverage prepared either from sorghum, maize, millet or their combinations. Togwa is popular in Tanzania and use directly as a weaning food or diluted refreshment beverage. The fermentation is carried out at ambient temperature, by the lactic acid bacteria e.g. *Lactobacillus fermentum*, *Pediococcus pentosaceus* *Lactobacillus brevis*, *Lactobacillus cellobiosus*, *Lactobacillus plantarum*, and yeasts e.g. *Saccharomyces cerevisiae*, *Candida pelliculosa*, *Candida tropicalis*, (Mugula *et al.*, 2003).

#### **Fura**

Fura is a fermented cereal based a popular drink in Northern Nigeria. It is a thick dough ball like snack produced mainly from sorghum or millet with the addition of spices. It is also served as a combination “*fura-de-nono*” dish which consists of millet balls and milk and is famous in northern Nigeria (Nkama and Gbenyi, 2001). The sorghum or millet is soaked in water overnight in calabash to ferment the grains. The soaked grains are sun dried and ground into fine powder and a smooth paste is formed in boiled hot water. The paste is moulded into balls and left for 1-4 days at room temperature to ferment it. The fermentation is carried out by lactic acid bacteria includes members of the genera *Lactobacillus*, *Pediococcus*, *Streptococcus*, *Leuconostoc* and *Enterococcus*. The most commonly isolated species is *L. plantarum* (Olasupo *et al.*, 1997). *Pediococcus* species predominated in the latter stage of the fermentation reported by Nche *et al.* (1994). Among the yeasts isolated was *Issatchenkia orientalis* which dominated in fura processing, followed by *Saccharomyces cerevisiae*, *Pichia anomala* and other *Candida spp.* After fermentation balls are pounded and moulded before sun drying. The sun dried balls are then milled into powder which can be further reconstituted with water to get fura meal/ beverage (Inyang and Zakari, 2008).

#### **Sake**

Sake is traditional rice based alcoholic beverage. It is also called as rice wine and popular in Japan and China (Lotong, 1998). To prepare the *Sake* rice is firstly polished then steamed and a steamed portion is used to grow *Aspergillus oryzae*, which activate different types of enzymes required for sake brewing. The seed mash is traditionally obtained by natural lactic acid fermentation involving various aerobic bacteria, wild yeasts, lactic acid bacteria, and *Sake* yeasts (Lotong, 1998; Yokotsuka & Sasaki, 1998).

#### **Pachwai**

Pachwai is a Indian rice beer mainly drink in North India. It is rice based with a starter culture *Bakhar*. Powdered starter ‘*Bakhar*’ is added to steamed rice and allowed to ferment for 24 hours. The whole mass is then transferred to earthenware jars, water is added and fermentation continues. The beer develops a characteristic alcoholic flavour and is ready to drink in 1 or 2 days. Nature of fermentation is Alcoholic fermentation and microorganisms involved in this fermentation are *Rhizopus spp.*, *Mucor spp.* and *yeast*

### Health benefits of fermented foods

#### **1. As a probiotics:**

*Lactobacillus plantarum* has been linked to reduced inflammatory bowel, small bowel bacterial overgrowth in children, reduced problems for sufferers of irritable bowel syndrome, and had a positive effect on the immune systems of those suffering from HIV. Bifidobacteria has been linked to decrease cases of neonatal necrotizing enterocolitis. Many strains of probiotics have been directly linked to reduced bouts of digestive complaints including diarrhea. *Lactobacillus acidophilus* also shown a preventative effect for polyps, adenomas, and colon cancer.

#### **2. Source of nutrition:**

Fermentation increase the digestibility and nutritional value of cereals based foods. Cereals based fermented foods protect the body against age-related diseases such as diabetes and cardiovascular diseases. Cereals also contain micronutrients such as vitamin E, folates, phenolic acids, zinc, iron, selenium, copper, manganese,



carotenoids, betaine, choline, sulphur amino acids, phytic acid, lignins, lignans, and alkylresorcinols which provide various types of health benefits.

**3. Flatulence reducing effect:**

During fermentation of the beans for preparation of tempe, the trypsin inhibitor is inactivated, and the amount of several oligosaccharides which usually cause flatulence are significantly reduced (Hesseltine, 1983).

**4. Anticholesterolemic effect:**

Hepner et al. (1979) reported hypercholesteremic effect of yoghurt in human subjects receiving a one-week dietary supplement. Studies on supplementation of infant formula with *Lb. acidophilus* showed that the serum cholesterol in infants was reduced from 147 mg/ml to 119 mg/100 ml (Harrison & Peat, 1975).

**5. Anticancerogenic effect:**

Anticarcinogenic effect of fermented foods showing potential role of *lactobacilli* in reducing or eliminating procarcinogens and carcinogens in the alimentary canal (Mital & Garg, 1995).

**6. Provide functional components:**

Fermented cereals can also contain a high mineral content and generally have a lower fat percentage than their dairy-based counterparts, but grains are generally lacking in essential amino acids. These forms of beverages can also naturally provide plant-based functional components, such as fibre, vitamins, minerals, flavonoids and phenolic compounds, which can effect oxidative stress, inflammation, hyperglycemia and carcinogenesis (Wang et al., 2013)

## Conclusion

Fermentation play an essential role in conferring the required stability, safety and sensory properties of the food products. Many cereal-based fermented foods play an excellent role as functional foods. They have beneficial effect on target functions in the body and contribute to the prevention and reduction of many diseases. Cereals are good substrate for fermentation because these are rich in nutrients. Cereal-based fermented foods are making major contributors to energy intake around the world. Fermented cereal foods play an important socio-economic role in developing countries. Fermented foods provides lot of health benefits to our body by consuming them. Lactic acid bacteria and yeasts are the predominant microorganisms during the cereals fermentation. The activities of lactic acid bacteria produce many antimicrobials and inhibitory substances during fermentation while the yeast contributes to flavour enhancement. A nutritional benefit of lactic acid fermentation is degradation of anti-nutritional factors and increased mineral bio-availability, improvement of protein digestibility of tannin-rich cereals, and degradation of flatulence-causing oligosaccharides.

## References

- [1]. A. Blandino, M.E. Al-Aseeri, S.S. Pandiella, D. Cantero, C. Webb. (2003). Review- Cereal-based fermented foods and beverages. *Food Research International*, 36, 527–543.
- [2]. Achi, O.K., & Ukwuru, O. (2015). Cereal-Based Fermented Foods of Africa as Functional Foods. *International Journal of Microbiology and Application*, 2(4), 71-83.
- [3]. Achi, O.L., & Ukwuru, M. (2015). Cereal Based Fermented Foods of Africa as Functional Foods, *International Journal of Microbiology and Application*, 2(4), 71-83.
- [4]. Achi, O.K. (2005). The potential for upgrading traditional fermented foods through biotechnology. *African Journal of Biotechnology*, 4(5), 375-380.
- [5]. Adams, M., & Mitchell, R., (2002). Fermentation and pathogen control: a risk assessment approach. *International Journal of Food Microbiology*, 79, 75-83.
- [6]. Ajanaku, K.O, Ajanku, C.O, Edobo-Osoh, A., & Nwinyi, O.C. (2012). Nutritive value of sorghum ogi fortified with groundnut seed. *American Journal of Food Technology*, 7(2), 82 – 88.
- [7]. Ashenafi, M. (1993). Ethiopian Enjera. In K. H. Steinkraus (Edition), Handbook of Indigenous Fermented Foods, 182–194, New York: Marcel Dekker.
- [8]. Badmos, A.H.A., Kayode, R.M.O, Amali, H.E., Ahmed, O., Adeyemi, K.O. (2014). Fermentation and West African food culture. A Review. *Global journal of Bio Science and Biotechnology*. 3 (2), 128-132.

- [9]. Banigo, E. O. I. (1993). Nigerian ogi. In K. H. Steinkraus (Edition.), Handbook of Indigenous Fermented Foods, 212–222. New York: Marcel Dekker.
- [10]. Beck, E.J, Tapsell, L.C., Batterham, M.J, Tosh, S.M., & Huang, X.F. (2010). Oat beta glucan supplementation does not enhance the effectiveness of energy-restricted diet in overweight women. *British Journal of Nutrition*, 103(8), 1212 – 1222.
- [11]. Blandino, A., Al-Aseeri, M. E., Pandiella, S. S., Cantero, D. & Webb, C. (2003). Cereal-based fermented foods and beverages. *Food Research International*, 36, 527-543.
- [12]. Blandino, A., Al-Aseeri, M. E., Pandiella, S. S., Cantero, D., & Webb, C. (2003). Cereal-based fermented foods and beverages. *Food Research International*, 36, 527-543.
- [13]. Blandino, A., Al-Aseeri, M.E., Pandiella, S.S., Canterob, D., & Webb, C. (2003). A Review: Cereal-based fermented foods and beverages. *Food Research International Journal*, 36, 527-543.
- [14]. Charalampopoulos, D., Wang, R., Pandiella, S.S., & Webb, C. (2002). Application of cereals and cereal components in functional foods. *International Journal of Food Microbiology*, 79, (1-2), 131 – 141.
- [15]. Chavan, J. K., & Kadam, S. S. (1989). Critical reviews in food science and nutrition. *Food Science*, 28, 348–400.
- [16]. Chavan, J. K., & Kadam, S. S. (1989). Food Science. *Critical reviews in Food Science and Nutrition*, 28, 348–400
- [17]. Das, A. J. & Deka, S. C. (2012). Fermented foods and beverages of the North-East India. *International Food Research Journal*, 19(2), 377-392.
- [18]. De Vuyst, L., & Neysens, P. (2005). The sourdough microflora: biodiversity and metabolic interactions. *Trends in Food Science and Technology*, 16, 43–56.
- [19]. Economidou, P.L., & Steinkraus, K. H. (1993). Greek trahanas. In K. H. Steinkraus (Ed.), Handbook of indigenous fermented foods, 299–304. New York: Marcel Dekker.
- [20]. Egounlety, M. (2002). Production of legume-fortified weaning foods. *Food Research International*, 35, 233-237.
- [21]. Fleet, G. H. (1998). The microbiology of alcoholic beverages. In J. B. Wood (Ed.), Microbiology of Fermented Foods (pp. 217–262). London: Blackie Academic and Professional.
- [22]. Gebrekidan, B., & Gebrettiwat, B. (1982). Sorghum injera: preparation and quality parameters. In ICRISAT, Proceedings of International Symposium on Sorghum Grain Quality, 55–56, Patancheru, India.
- [23]. Grajek, W., Olejnik, A., & Sip, A. (2005). Probiotics, prebiotics and antioxidants as functional foods. *Acta Biochimica Polonica*, 52, 665-671.
- [24]. Hammes, W.P., & Ganzle, M.G. (1998). Sourdough breads and related products. *Microbiology of Fermented Foods*, 1, 199-216.
- [25]. Hepner G, Fried RR, Jeor SS, Fuseti L & Morin R (1979). Hypercholesteremic effect of youghur and milk. *American Journal of Clinical nutrition*, 32, 19.
- [26]. Hesseltine CW (1983). The future of fermented foods. *Nutrition Reviews*, 41, 293-301.
- [27]. Holzapfel, W.H., & Schillinger, U. (2002). Introduction to pre- and probiotics. *Food Research International*, 35, 109- 116.
- [28]. Hugenholtz, J., & Smid, E. D. (2002). Nutraceutical production with food grade microorganisms. *Current Opinions in Biotechnology*, 13, 497-507.
- [29]. Inyang, C.U., & Zakari, U.M. (2008). Effect of germination and fermentation of pearl millet on proximate chemical sensory of instant fura – A Nigeria cereal food. *Pakistan Journal of Nutrition*, 7(1), 9 - 12.
- [30]. Jakobsen, M. & Lei, V. (2004). Microbiological characterization and probiotic potential of koko and koko sour water, an African spontaneously fermented millet porridge and drink. *Journal of Applied Microbiology*, 96, 384-397.
- [31]. Jespersen, L. (2003). Occurrence and taxonomical characteristics of strains of *Saccharomyces cerevisiae* predominant in African indigenous fermented foods and beverages. *FEMS Yeasts Research*, 3, 191-200.
- [32]. Kalui, C. M., Mathara, J. M. & Kutima, P. M. (2010). Probiotic potential of spontaneously fermented cereal based foods – A review, *African Journal of Biotechnology*, 9(17), 2490-2498.
- [33]. Kalui, C.M., Mathara, J.M., & Kutima, P.M. (2010). Probiotic potential of spontaneously fermented cereal based foods – A Review. *African Journal of Biotechnology*, 9(17), 2490-2498.
- [34]. Kalui, C.M., Mathara, J.M., Kutima, P.M., Kiiyukia, C., & Wongo, L.E. (2008). Partial characterization and identification of lactic acid bacteria involved in the production of ikii: a traditional fermented maize porridge by the Kamba of Kenya. *Journal of Tropical Microbiology and Biotechnology*, 4(1), 3-15.
- [35]. Kalui, C.M., Mathara, J.M., Kutima, P.M., Kiiyukia, C., Wongo, L.E. (2009). Functional characteristics of *Lactobacillus plantarum* and *Lactobacillus rhamnosus* from ikii, a Kenyan traditional fermented maize porridge. *African Journal of Biotechnology*, 8(17), 4363-4373.
- [36]. Kohajdova, Z., Karovicova, J. (2007). Fermentation of cereals for specific purpose. *Journal of Food and Nutrition Research*, 46, 2, 51-57.
- [37]. Kuboye, A. O. (1985). Traditional fermented foods and beverages of Nigeria. In Proceedings of the International Foundation for Science (IFS)/United Nations University (UNU). Workshop on Development of indigenous fermented foods and Food technology in Africa, 225–236, Douala, Cameroon.

- [38]. Lee, J. H., Lee, S. K., Park, K. I., Hwang, I. K., Ji, G. E. (1999). Fermentation of rice using amylolytic Bifidobacterium. *International Journal of Food Microbiology*, 50, 155-161.
- [39]. Lei, V., & Jakobsen, M. (2004). Microbiological characterization and probiotic potential of koko and koko sour water, African spontaneously fermented millet porridge and drink. *Journal of Applied Microbiology*, 96, 384-397.
- [40]. Lopez, C.C., Serio, A., Tovar, C.D.G., Mulet, R.C., Ospina, J.D., & Paparella, A. (2014). Traditional Fermented Foods and Beverages from a Microbiological and Nutritional Perspective: The Colombian Heritage, *Food Science and Food Safety*, 13.
- [41]. Lopez, Y., Gordon, D. T., & Field, M. L. (1983). Release of phosphorous from phytate by natural lactic acid fermentation. *Journal of Food Science*, 48, 953-954.
- [42]. Lotong, N. (1998). Koji. In J. B. Wood (Edition.), *Microbiology of fermented foods*, 658-695, London: Blackie Academic and Professional.
- [43]. Mbata, T.I., Ikenebomeh, M.J., & Alaneme, J.C. (2009). Studies on the microbiological, nutrient composition and antinutritional contents of fermented maize flour fortified with bambara groundnut (*Vigna subterranean* L). *African Journal of Food Science*, 3(6), 156 - 171.
- [44]. McGovern, P. E., Zhang, J., Tang, J., Zhang, Z., Hall, G. R., Moreau, R. A., Nunez, A., Butrym, E. D., Richards, M. P., Wang, C. S., Cheng, G., Zhao, Z., Wang, C. (2004). Fermented beverages of pre- and proto-historic China. *Proceedings of the National Academy of Sciences*, 101, (51), 17593-17598.
- [45]. Mensah, P. (1997). Fermentation - the key to food safety assurance in Africa. *Food Control*, 8, 271-278.
- [46]. Mensah, P. P. A., Tomkins, A. M., Drasar, B. S., Harisson, T. J. (1990). Fermentation of cereals for reduction of bacterial contamination of weaning food in Ghana. *Lancet*, 336, 1990, 140-143.
- [47]. Mital BK & Garg SK (1995): Anticarcinogenic, hypoholesterolemic and antagonistic activities of *Lactobacillus acidophilus*. *CRC Critical Reviews in Microbiology*, 21, 175-214.
- [48]. Mokoena, M.P., Chelule, P.K., & Galeni, N. (2005). Reduction of fumonisin B1 and zearalenone by lactic acid bacteria in fermented maize meal. *Journal of Food Protection*, 68, 2095-9.
- [49]. Mugula, J. K., Sorhaug, T., & Stepaniak, L. (2003). Proteolytic activities in togwa a Tanzanian fermented food. *International Journal of Food Microbiology*, 84, 1-12.
- [50]. Nche, P.F., Nout, M.J.R., & Rombouts, F.M. (1994). The effect of Cowpea Supplementation on the quality of Kenkey, A traditional Ghanaian fermented food. *Journal of Cereal Science*, 19, 191 - 197.
- [51]. Nkama, I., & Gbenyi, D.I. (2001). The effect of malting of millet and sorghum on the residual phytate and polyphenols in Dakuwara, Nigerian cereal-legumes snack food. *Journal of Tropical Agriculture*, 44, 270 - 275.
- [52]. Olasupo, N.A., Olukova, D.K., & Odunfa, S.A. (1997). Identification of *Lactobacillus* species associated with selected African fermented foods. *Zeitschrift für Naturforschung*, 5: 105 - 108.
- [53]. Parker, M. L., Melaku, U., & Faulks, R. M. (1989). The contribution of flour components to the structure of injera, Ethiopian fermented bread made from tef. *Journal of Cereal Science*, 10, 93-104.
- [54]. Platt, C. G. (1994). Fermented foods: a world perspective. *Food Research International Journal*, 27, 253.
- [55]. Ramakrishnan, C. V. (1993). Indian idli, dosa, dhokla, khaman, and related fermentations. In K. H. Steinkraus (Edition), *Handbook of indigenous fermented foods*, 149-165. New York: Marcel Dekker.
- [56]. Reid, G. (2008). Probiotics and prebiotics—progress and challenges. *International Dairy Journal*, 18, 969-975.
- [57]. Ross, R. P., Morgan, S., & Hill, C. (2002). Preservation and fermentation: past, present and future. *International Journal of Food Microbiology*, 79, 3-16.
- [58]. Rowan, N. J., Anderson, J. G., & Smith, J. E. (1998). Potential infective and toxic microbiological hazards associated with the consumption of fermented foods. In J. B. Wood (Edition), *Microbiology of fermented foods*, 812-837. London: Blackie Academic and Professional.
- [59]. Salovaara, H. (1988). Lactic acid bacteria in cereal-based products. In: Salminen S, von Wright A, ed. *Lactic acid bacteria - Microbiology and functional aspects*. New York, NY: Marcel Dekker, 115-1
- [60]. Sanni, A. I. (1993). The need for process optimization of African fermented foods and beverages. *International Journal of Food Microbiology*, 18, 85-95.
- [61]. Shah, N.P. (2007). Functional cultures and health benefits – A review. *International Dairy Journal*, 17, 1262-1277.
- [62]. Shortt, C. (1998). Living it up for dinner. *Chemistry and Industry*, 8, 300-303.
- [63]. Steinkraus, K.H. (1983). Lactic acid fermentation in the production of foods from vegetables, cereals and legumes. *Antonie van Leeuwenhoek*, 49, 337-348.
- [64]. Steinkraus, K.H. (1996). *Handbook of Indigenous Fermented foods*, Marcel Dekker, New York 1996.
- [65]. Svanberg, U., & Lorri, W. (1997). Fermentation and nutrient availability. *Food Control*, 319-327.
- [66]. Vanegas-Gamboa, D.C., Betancourt-Botero, D.P., Ramirez-Toro, C.M.S., Bolivar, G. (2009). Research of the inhibitory capacity of lactic acid bacteria isolated from corn sourdough. III Simposio Internacional de Bacterias L'acticas, September 15-17, 2009, Tucumán, Argentina, 155.



- [67]. Vasiljevic, T., & Shah, N.P. (2008). Probiotics from Metchnikoff to bioactives, Review Article. *International Dairy Journal*, 18, 714-728.
- [68]. Wang, Chung-Yi, Sz-Jie Wu, and Y.- T. S. (2013). Antioxidant properties of certain cereals as affected by food - grade bacteria fermentation. *Journal of Bioscience and Bioengineering*.
- [69]. Wood, B.J.B, Holzapfel, W.H. (1995). The genera of lactic acid bacteria in the lactic acid bacteria: Edited by B.J.B Wood and W.H Holzapfel. Blackie Academic and Professional, London. 398.
- [70]. Yokotsuka, T., & Sasaki, M. (1998). Fermented protein foods in the orient: shoyu and miso in Japan. In J. B. Wood (Edition), *Microbiology of fermented foods*, 351–415. London: Blackie Academic and Professional.
- [71]. Yokotsuka,T., & Sasaki, M. (1998). Fermented protein foods in the orient: shoyu and miso in Japan. In J. B. Wood (Edition), *Microbiology of fermented foods*, 351–415, London: Blackie Academic and Professional.
- [72]. Zegeye, A. (1997). Acceptability if injera with stewed chicken. *Food Quality and Preference*, 8, 293–295.