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Review on Technology and Microbiology of Traditionally Fermented Food and Beverage Products Of Ethiopia

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ABSTRACT

Fermented food and beverage products are made globally by using different practices, fresh materials and microbes. Fermented foods serve as ample sources of essential vitamins, minerals, enzymes, and antioxidants that are all enhanced through the process of fermentation. Globally, fermented beverage and condiments are made by using different conventional practices, raw materials, and microorganisms. In Ethiopia, fermented beverage and condiment products have practiced in a long history. The advantageous effects related with fermented products have a special prominence during the production of these products in unindustrialized countries like Ethiopia. In the production of traditional fermented food and beverage products, controlled natural fermentation process with the absence of starter cultures are used to initiate it. In Ethiopia, the local fermented food and beverage products are usually manufactured through acid-alcohol type of fermentation. The preparation and consumption of many traditionally fermented food and beverage products is still practiced as a household art in Ethiopia. This paper presents useful in-sights on the technology and microbiology of local fermented food and beverage products of Ethiopia.

Key words: *Fermented food, kocho, keribo, Injera fermentation, Ergo (Sour Milk)*

INTRODUCTION

Background of the review

In developed and developing countries, traditional fermented food and beverage product forms an important part of the food. Therefore, these food products are prepared from plant and animal materials in which microbes play an important role by altering the material physically and nutritionally. Ethiopia is a country rich in cultural diversity, variety of foods and beverages, processed and consumed among the various ethnic groups are indicators of this diversity [1].

Ethiopia is one of the countries where a wide variety of traditional fermented foods and beverages are prepared and consumed. Fermented products prepared from plant and animal sources play an important role in human food due to changes in the physical, chemical, and nutritional properties by microorganisms. African raw plant and animal materials are predominated by many lactic acid bacteria (LAB) and yeasts. Predominance of specific yeast species seems to be largely product specific [1].

Fermentation of raw plant and animal material is one of the best known earliest methods of food preparation and preservation. Thus, fermented foods have a role in social functions such as marriage, naming and rain making ceremonies, where they are served as weaning foods. In addition, fermentation delivers a natural way to reduce the volume of the material to be transported, to extinguish undesirable components, to improve the nutritive value and appearance of the food, to reduce the energy required for cooking and to make a safer product [2].

Fermented food and beverage products are made globally by using different practices, fresh materials and microbes. Therefore, there are only four main fermentation processes involved, they are alcoholic, lactic acid, acetic acid and alkali fermentation [3].

Alcoholic fermentation marks in the production of ethanol, and yeasts are the major organisms. Lactic acid fermentation is produced by the presence of LAB. A second group of bacteria that plays important role in food fermentations are the acetic acid producers from the *Acetobacter* species. *Acetobacter* spp. converts alcohol to acetic acid in the existence of surplus oxygen. Alkali fermentation frequently takes place through the fermentation of fish and seeds, popularly known as condiment [4].

In Ethiopia there are several traditionally fermented foods some of which are products of a low technology process involving a solid state fermentation (SSF) system. The technique is usually cheap and simple to operate but can be time-consuming and labour-intensive. Biochemically, SSF is a complex system that has not been fully characterized and understood. The technology has been used in Ethiopia to produce such food items as kocho and bulla [15].

The advantageous effects related with fermented products have a special prominence during the production of these products in unindustrialized countries like Ethiopia. These effects resulted in decreased loss of raw materials, minimized cooking time, enhancement of protein quality and carbohydrate digestibility, upgraded bioavailability of micronutrients and removal of toxic and anti-nutritional factors [5].

The fermentation process has the ability to improve the organoleptic properties by producing different flavors in different foods [7]. In most of these products the fermentation is natural and involves mixed cultures of microbes. Thus, some microbes may participate in parallel, while others act in a sequential manner with an altering dominant biota during the course of fermentation. The common fermenting bacteria are species of *Leuconostoc*, *Lactobacillus, Streptococcus, Pediococcus, Micrococcus* and *Bacillus.* The fungal genera are *Aspergillus, Paecilomyces*, *Cladosporium, Fusarium, Penicillium* and *Trichothecium* [8]. Yeasts have been reported to be involved in various types of local fermented foods and beverage products and the most dominant yeast species accompanying with African indigenous fermented foods and beverage products is *Saccharomyces cerevisiae* [9].

It is known to the people of the world that race of Ethiopia has its own views and approaches relating to foods. Some of these are associated to foods and diseases, while others are to qualities, such as hot and cold or light and heavy foods [10]. However, the absence of a writing culture throughout the country marks their origin difficult to trace. Perhaps, the most accepted of the fermented foods production is started at 1970s. The nature of fermentation in Ethiopia is not complex and does not required expensive equipment. During production of traditional fermented food products in Ethiopia, it is common to use and follow controlled natural fermentation process with no defined starter cultures used to initiate it. Ethiopian local fermented foods and beverages are products of acid-alcohol type of fermentation. The preparation and consumption of many local fermented foods and beverages is still practiced at households in Ethiopia.

These include injera, ergo, Ititu, ayib, qibe, arrera, kocho, tella, awaze, borde and tejj. Thus, at different time different researchers conducted studies on the mentioned local traditional fermented food and beverage products. Bearing in mind the rich diversity in fermented food and beverage types in the country; few studies were carried out in widely different parts of Ethiopia, which included the major ethnic groups. Therefore, this paper presents the technology and microbiology of local fermented food and beverage products of Ethiopia.

Objective of the Review

The main objective of this review is to evaluate technology and microbiology of traditionally fermented food and beverage products of Ethiopia, and to gain an understanding of existing research in this area, which helps in the future for standardization of traditionally fermented food and beverage products of Ethiopia in future.

Significance of the Review

This review addresses the technology and microbiology of traditionally fermented food and beverage products of Ethiopia. These include injera, ergo, ayib, qibe, arera, kocho, tella, awaze, borde and tejj. The processing and fermentation process differs from product to product and the variations can be understood in this study. It also gives an in-sight into the type of microorganisms involved in fermentation process. The nutritional benefits and shelf life of the traditionally fermented beverages can be known from this study. Moreover, the information gathered will be useful for future research in this area.

2.REVIEW OF RELATED LITERATURE

2.1. Traditional Fermented Plant Foods

2.1.1. Injera fermentation

Injera is thin, fermented Ethiopian dish made from grains particularly, teff flour by mixing water and starter (ersho), which is a fluid, saved from previously fermented dough. Teff *(Eragrostis tef (Zucc)* Trotter) is the most widespread grain for making injera, although other grains such as sorghum, maize, barley, wheat and finger millet are sometimes used. Teff has the largest part of area (23.42%, 2.6 million hectares) under cereal cultivation and third (after maize and wheat) in terms of grain production (18.57%, 29.9 million quintals) in Ethiopia [11].

Due to its nutrition value, there is an increasing concern in teff grain utilization. For instance, the protein is essentially free of gluten. Gluten is a protein found in wheat, rye, barley and some lesser known grains. Generally, speaking the advantages of using gluten free diet translates to better health. However, people with celiac disease or allergies find the benefits of a gluten free diet to be life sustaining. Therefore, about 66% of Ethiopian nutrition covers of injera and it accounts for about two-third of the daily protein consumption of the Ethiopian population [12].

The preparation of teff injera comprises of two stages of natural fermentation, which last for about 1 to 3 days depending on ambient temperatures. The method of making injera from its raw materials to the final product involves mixing the ingredients (teff flour and water) to dough, which is fermented and subsequently thinned to a batter. The batter was left covered for 2 h for secondary fermentation. The batter was left for about 30 min to rise (the second fermentation), before baking commenced. The storage period of injera does not exceed three days at ambient temperature (temperature in the highlands of Ethiopia is between 17 and 25°C). It is a common practice to discard moldy injera. However, in times of food scarcity, moldy injera is sun dried and prepared for consumption [13].

After 2 to 3 min of cooking using traditional baking equipment (metad), the injera was removed and stored in a traditional basket container messob. According to report, a total of 34 samples from injera batter were collected during 96 h fermentation at 6 h intervals [14].

In a study, the teff sample was bought from Hawassa open market. A total of 107 LAB and 68 yeast strains were isolated and identified. The major LAB strains identified were *Pediococcus pentosaceus* (49.53%), *Lactobacillus fermentum* (28.04%), *Lactococcus piscium* (5.61%), *Lactococcus plantarum* (4.67%), *Pediococcus acidilactici* (3.74%), *Leuconostoc mesenteriodes* subsp. *mesenteriodes* (2.80%), *Lactococcus raffinolactis* (2.80%), *L.mesenteriodes* subsp. *dextranicum* (1.87%), *Enterococcus casseliflavus* (0.93%), and the yeast strains were

Saccharomyces cerevisiae (48.53%), *Candida humilis* (22.06%), *Candida tropicalis* (17.65%), *Saccharomyces exiguus* (7.35%) and *Pichia norvegensis* (4.4%). [14].

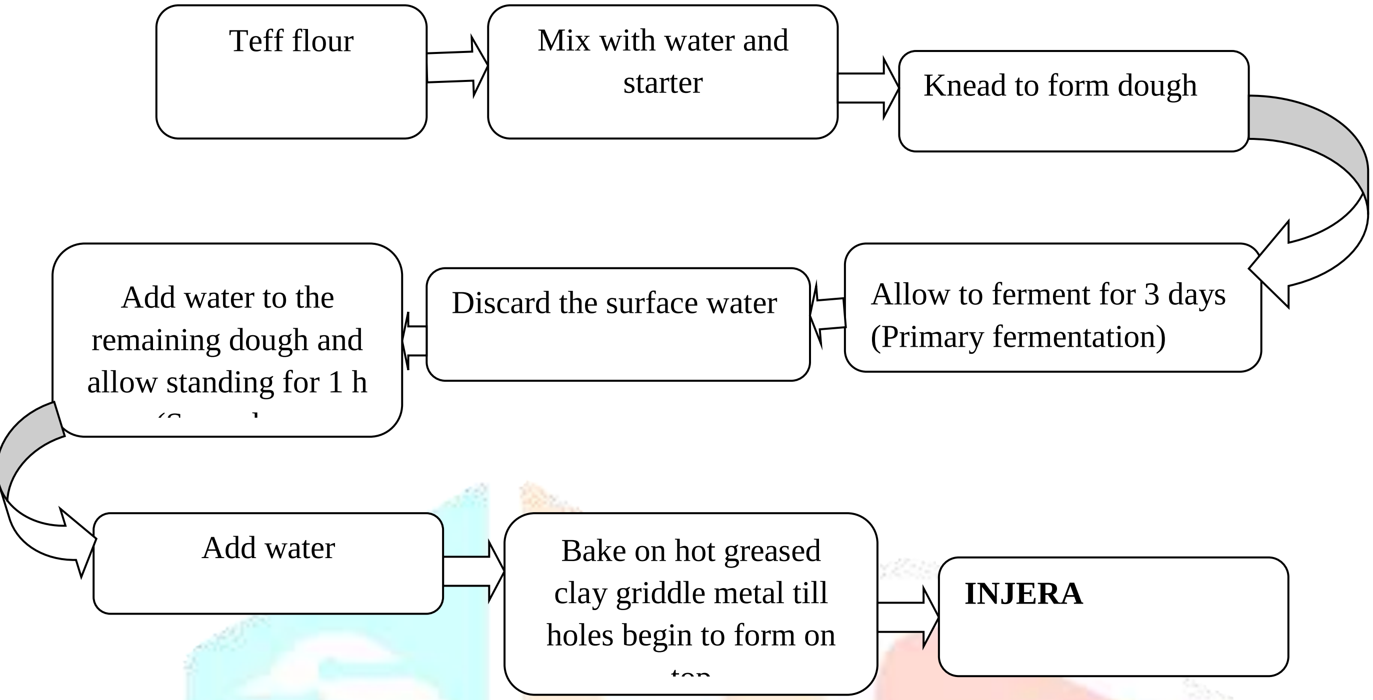

Figure 1. Flow diagram for the preparation of injera

NUTRITIONAL VALUE OF INJERA

2.1.2. Kocho fermentation

Enset (*Ensete ventricosum*) is considered as large soft tissue banana-like plant that grows up to 11 m high to the tip of the leaves [15]. Enset has been cultivated as main food crop in south and southwestern Ethiopia [16]. Records revealed that enset has been grown in Ethiopia for a long period [17]. Enset is used for different purposes such as human food, livestock feed, industrial fiber, as rob material in fences and house-building, for mattresses and seats making, as local packaging material, and as substitute for table plates or umbrellas [15].

The plant is drought tolerant and grows throughout the year; it has the capability to serve for more number of people in the future as staple foods. Currently, the Ethiopian government has started a project on enset plant adaptation to non-enset growing regions (such as Tigray and Amhara) of the country. Nevertheless, the information on the microorganisms involved and the biochemical changes occurred during the fermentation processes are not well studied [16].

During fermentation of kocho, the value of pH gradually decreases and the number of microorganisms increases. The decrease in pH and increase in titrable acidity during the entire kocho fermentation could be attributed to the activities of acid producing microorganisms mainly LAB and yeast. At the initial fermentation Enterobacteriaceae increased and thereafter counts of Enterobacteriaceae reached below detectable level [18]. And also according to study on *in vitro* characteristics of LAB isolated from Ethiopian traditional fermented shamita and kocho for their desirable properities as probiotics, the LAB like *Lactobacillus*, *Leuconostoc*, *Pediococcus* and *Lactococcus* were found in kocho. Moreover, that *Lactobacillus* isolates were the most frequently isolated groups from kocho samples followed by *Leuconostoc* [19].

NUTRITIONAL VALUE OF FERMENTED KOCHO

2.2. Traditional Fermented Dairy Products

In a long history, fermented dairy products are made from domesticated milk animals. Milk is known as the most nutritious food due to its rich nutrient content. It is an excellent source of proteins, minerals (especially calcium and phosphorus) and vitamins. It is known that, fermented milk products are widely spread throughout the world. Fermentation of milk is carried out by the activities of natural flora present in the food or added from the surroundings. Hence, the microbes mainly encountered on the dairy industry are LAB, AMB, coliforms, Enterobacteriaceae, yeasts, molds and viruses. Some bacteria such as LAB are useful on milk processing, causing milk to sour naturally, and leading to fermented products. These products were an important component of nutritional food during young age. Alongside, natural milk can also contain pathogenic bacteria, such as *Salmonella* species, *Mycobacterium tuberculosis*, *Listeria* species, and *Brucella* species, and can thus transmit disease and produce poor yields of products [20].

Traditional dairy fermentation process is conducted naturally without controlling the fermentation processes. Due to this, fresh milk is left at room or ambient temperature to assist fermentation process. In rural areas, especially among the pastoralists, raw milk is mostly kept in properly smoked container which is used for killing any organism remaining after washing, this improves smell of equipment, improved aroma of butter when used as hair dressing and improved taste. And fermented milk from a previous fermentation can be used as source of inoculums. In addition to this, LAB from the internal surface of the container can also serve as starter culture. Regarding the quality and taste of the fermented product, the incubation temperature does have significant role in the lowlands. In Ethiopia, the main fermented milk products include ergo, ititu, ayib, kibe, arerra, etc [20].

2.2.1. Ergo (Sour Milk)

Ergo is a naturally processed native Ethiopian fermented milk product, which is usually prepared at house level. It is made by natural fermentation of milk under ambient temperature. As a result, the microbial load of fermented milk samples, including Ergo, could vary from sample to sample based on the microbial number and types of microorganisms in the original raw milk [21].

During ergo fermentation, LAB was the dominant organism when compared to all other microorganisms, followed by yeasts and then molds. Ergo fermentation is usually carried out by the genera, *Lactobacillus*, *Lactococcus, Leuconostoc, Enterococcus* and *Streptococcus* (LAB). And also the same authors also revealed that *Micrococcus* species, coliforms and spore formers were also present in fairly high numbers during the first 12 to 14 h of fermentation [22]. The result from the previous studies demonstrated that there are diverse LAB (homofermentative and hetrofermentative) in raw cow's milk [22]. The presence of LAB in milk and milk products enhances bioavailability of nutrients, act as a preservative and serve as source for beneficial lactic acid.

The fermentation is performed majorly to improve the taste and/or flavor of the milk products and/or to increase the shelf life. Traditional milk preparation techniques involve smoking of processed utensils using residues of *Olea africana.* This smoking practice is useful to keep better quality of ergo through its inhibitory effect on spoilage and pathogenic organisms. To control the harmful microbes, the lower pH of ergo is more effective after 24 h of incubation. At this time, the ergo is considered to be too sour for direct consumption since ergo coagulates within 24 h and preferably consumed at this time for its good flavor [26].

2.2.2. Kibe (traditional butter)

Traditionally, Ethiopian butter is the most shelf stable of all traditionally processed of fermented dairy foodstuffs and has always been made from sour milk. It is semi-solid at room temperature with white and sometimes yellowish color, depending on age. It has a typical diacetyl taste and flavor when fresh, but extended storing at room temperatures results in putridity and rancidity. Butter is important component of Ethiopian traditional fermented milk products. This traditional milk product is processed and sold by women in every society. It has been used by women for hair dressing and also used as the source of diet both in rural and urban areas, and is also utilized by children of weaning age and the elderly [27].

According to report, the average total bacterial counts (TBC) ranged from 6.18 log cfu/g in butter samples collected from Selale area to 7.25 log cfu/g samples from Sululta [28] .On other studies, the average TBC of 7.49 log cfu/g and the presence of high variability among samples depending on the sources were reported. Samples collected from open markets and rural producers, for instance, had higher counts as compared to that obtained from dairy farms and urban producers of southern Ethiopia. In addition to this, the TBC of fresh butter sampled from rural and public butter markets in Addis Ababa ranged from 8.27 to 4.7 log cfu/g of butter [29].

MICROORGANISM INVOLVED IN FERMENTATION

2.2.3. Arera (defatted sour milk)

Arrera is byproduct of ergo obtained after removal of kibe after churning. It has a similar color to ergo, but its appearance slightly smoother, although thicker than fresh milk and basically contains the casein portion of milk. In contrast to other traditional dairy products, arrera has fewer calories. It contains 91.5% moisture, 3.1% protein, 1.4% fat, 3.4% carbohydrate, and 0.6% ash [30]. And also arrera has a shorter shelf life compared to all other fermented milk products (only 24 to 48 h). It is consumed in all parts of the country where fermented milk is made and it serves as a beverage either plain or spiced. It is chosen by women for consumption as a side dish or as drink. Extra of the products are given to calves, lactating cows and dogs. However, it may indirectly serve as additional income for the women by its use as raw material for cottage cheese (ayib) manufacture, which may be sold in the market. Due to its relatively short shelf life and some traditional beliefs, arrera is not sold in the market for direct consumption [16].

The average counts of total bacteria, Entero-bacteriaceae and coliforms were greater than 9, 4.7 and 4.2 log cfu/ml, respectively of arera sampled from Addis Ababa [28]. The same author also reported coliform count of 4.86 log cfu/ml. Different species of bacteria were identified in arera samples collected during both dry and wet seasons, which include *Klebsiella pneumoniae*, *Klebsiella oxytoca*, *Escherichia cloacae*, *Escherichia sakazakii*, *Escherichia coli* and some species of *Salmonella* [31].

2.2.4. Ayib (Ethiopian cottage cheese)

Ayib, a traditional Ethiopian cottage cheese, is a popular milk product consumed by the several local groups of the country. It is prepared from sour milk after the butter is removed by churning. Churning of the sour milk is carried out by slowly shaking the contents of the pot until the butter is separated. The defatted milk is heated to about 50°C until a distinct curd forms. It is then allowed to cool slowly, and the curd is filtered through a muslin cloth. Ayib comprises 79% water, 14.7% protein, 1.8% fat, 0.9% ash and 3.1% soluble milk constituents [29].

In a study on the microbiological quality of ayib, samples collected from an open market in Awassa had counts of mesophilic aerobic bacteria (AMB), yeasts and enterococci of 10^8, 10^7 and 10^7 cfu/g, respectively [32].

Above 60% of the samples had psychotropic count of 10 log cfu/g and about 55% of the samples were positive for coliforms and fecal coliforms. The pH values of the samples varied between 3.3 and 4.6 with about 40% having pH lower than 3.7. During preparation of ayib, the high initial count of microbes in milk, which raises the fermentation process, is shown to fall by the combined action of cooking and low pH. The presence of high microbial load of ready-to-consume ayib is assumed to be introduced from plant parts used for packaging and imparting flavor, and from handlers, too. Its low pH value should also assist in maintaining the low count for a certain period of time [34].

A considerably lower pH due to the activity of LAB may result in a too sour product with a low sensory quality. A Study has been done by showing the incompatible effect of mixed lactic cultures against foodborne pathogens (*Escherichia coli*, *Salmonella Typhimurium* DT104 and *S. aureus*) were evaluated during preparation and storage of ayib [33]. Ayib was prepared by cooking pasteurized milk product with the numerous mixed starter cultures. The test pathogens were separately inoculated in duplicates into 200 g of cooled ayib in sterile stomacher bags to give initial inoculum level of 6 log cfu/g mixed thoroughly and incubated at ambient condition. Separately, ayib samples was similarly processed and stored at refrigeration condition. Enumeration of pathogens was done at 24 h intervals for 9 days. When counts were <log1 cfu/g, enrichment followed by streaking on the nutrient agar plates were done to determine complete inhibition [34].

In milks soured in the presence of mixed starter LAB cultures, the test organisms (TOS) were reduced by 2 and 4 log factors at 24 and 48 h, respectively. The pH of souring milk was about 4.0 at 48 h. In the control milks (milks inoculated with test pathogens in the absence of LAB), the test pathogens grew to 8.4 log cfu/g at 48 h. The mean pH value of control milks dropped from initial 6.44 to 5.43.

2.3. Traditional Fermented Beverages

2.3.1. Tella fermentation

Tella is popular Ethiopian traditional beverages, which is made from diverse ingredients. *Tella* has various vernaculars in the various regions and is a malt beverage based on substrates such as barley, wheat, maize, millet, sorghum, teff or other cereals. It is, by far, the most commonly consumed alcoholic beverage in Ethiopia. It is assumed that over two million hectoliters of tella to be brewed and consumed annually in households in Addis Ababa alone [35].

Some of them consider as local beer. It is traditionally drunk on major religious festivals, saint's days and weddings. Depending on the type of cereal ingredients used to make, tella has different names: Amhara tella, Oromo tella, and Gurage tella [36]. Amhara tella has gesho (*Rhamnus prinoides*) and concentrated. Gurage tella is delicately aromatized with a variety of spices. Oromo tella has no gesho (*R. prinoides*), and it is thick and sweet. Generally, tella is brewed from substrates such as barley, wheat, maize, millet, sorghum, teff or other cereals. The quality of tella is variable from local to local, from individual to individual. Even within the same individual, the quality is variable from time to time [37].

The extent of heat treatment the asharo (roasted barley) receives and the degree of steaming the enkuro (roasted barley steamed after grinding) is subjected to have the direct bearing on the color of tella, which is determined by the housewife preparing the tella. Tella is actually a beverage of variable viscosity and having a variety of colors (grayish-white to dark brown) [42]. Several samples of tella and other traditional alcoholic beverages collected from three regions of Ethiopia (Gojam, North Shoa, and Addis Ababa) were analyzed for their ethanol, methanol, and fuel oil contents. The mean values for methanol, fuel oil, and ethanol were found to be 35 ppm, 66 ppm, and 3.6%, respectively [36].

According to a report there were no microbes at the end of tella fermentation phase, especially in tella made with gesho. This is because of the synergic effect of both *R. prinoides* antibacterial substance, high alcohol concentration, reduction of pH as fermentation time increases and reduction of nutrient content of tella. Moreover, yeasts were dominated at the middle of tella fermentation phases but at the last phase, they were dramatically reduced. Gesho and bikil (malt) were main sources of yeasts and bikil was the major source of LAB. Acetic acid bacteria were not detected from any ingredient; similarly Enterobacteriaceae and yeasts were not detected in ashero and kita [40].

Therefore, the counts of *Lactobacillus, Lactococcus,* yeasts and AMB showed increment during the first two phases in both fermenters but gradually reduced at phase IV in both fermenters. The counts of Enterobacteriaceae were high at day zero and not detected at phase II in both fermenters. Acetic acid bacteria were detected at the beginning of phase II in traditional fermenter but not at phase III in modified fermenter. In line with this, indicated that based on the nature of the ingredients of tella, the distribution of the microbial community is variable [40].

2.3.2. Tej fermentation

Tej is a honey wine with alcohol content varying from 8 to 14% ABV, which is made from honey, water and leaves of gesho. Previously, upper class used to consume tej, but now it is widespread among all social groups, consumed on holidays and at weddings as well as served in hotels and bars across the country. It is a home-based as well as commercially available honey wine. So tej is mainly used for great feasts, such as weddings and the breaking of fasting. Sometimes, widely for commercial purposes, mixture of honey and sugar could be used for its preparation. In cases where sugar is used as part of the substrate, natural food coloring is added so that the beverage attains a yellow color similar to that made from honey [36].

Tej fermentation, like other traditional beverages of Ethiopia, is a natural fermentation and no starter culture or other modern techniques are used. So, the fermentation depends upon the microorganisms present in the environment. Thus, to determine the major source of the yeast cells in *tej* attention was given to honey and gesho. The dominant yeast, *S. cerevisiae*, counts ranged from 102 to 103 cfu/g in gesho samples while 0 to 102 cfu/g in honey samples. And gesho was considered the major source of the dominant yeast in *tej* because it contained greater number of the yeast than honey [44].

During the preparation of *tej*, the fermentation pot is seasoned by smoking over smoldering *R. prinoides* stems and olive wood. One part of honey mixed with 2 to 5% (v/v) parts of water is placed in the pot, covered with a cloth for 2 to 3 days to ferment after which wax and top scum is removed [44].

Some portion of the must is boiled with washed and peeled *R. prinoides* and put back to the fermenting must. The pot is covered and fermented continuously for another 5 days, in warmer weathers, or for 15 to 20 days, in colder cases. The mixture is stirred daily and finally filtered through cloth to remove sediment and *R. prinoides*. Good quality tej is yellow, sweet, effervescent and cloudy due to the content of yeasts. The flavor of *tej* depends upon the part of the country where the bees have collected the nectar and the climate [44].

2.3.3. Borde fermentation

Borde is a local beer mostly consumed by people in southwestern parts of the country. It is considered as a drink for people in the lower socio-economic status. Borde is prepared by women from fermented maize, sorghum, barley, or a mixture of the three. Borde can be very thick and serve as a substitute for meals during long trips. According to the villagers attitude borde is also used for medical and ritual purposes. The users consider that it enhances lactation and mothers are encouraged to drink substantial amounts of it after giving birth [41].

Borde is produced by natural fermentation of a diversity of locally available cereal ingredients. *Borde* is one of the various nutritious and low alcoholic traditional fermented beverages in Ethiopia. The scaling up of such products, although important, may have to be undertaken with great care so as not to lose the nutritive value as well as the public acceptance of the beverages. It is a gassy whitish-grey to brown colored beverage with thick consistency and sweet-sour taste. Fermentation of borde has four phases marked by the introduction of ingredients into the fermentation pot at different times. In phase I (primary fermentation), maize grits were mixed with water and left to ferment at ambient temperature in a clean insira for 48-72 h [41].

A portion of the fermented grits from phase I (48 h) was roasted on a mitad into enkuro, a well-roasted granular mass. Fresh malt flour and water were carefully mixed by hand in a smoked insira into a pale brown thick mash. This mixture is called tinsis and it was left to ferment for 24 h. A second portion of the fermented grits from phase I (68 h) was slightly roasted into enkuro, carefully kneaded with mixed flour (wheat, finger millet and teff) and water, and then moulded into stiff dough balls. The dough balls were steamed into gafuma and then broken into pieces.

Pieces of cooled gafuma were blended with the fermented tinsis and additional water in the same insira to a thick brown mash called difdif. The difdif was then allowed to ferment for 18 h [41].

Samples of borde from open markets at five localities in southern Ethiopia showed average aerobic mesophilic count (AMC), LAB and yeast counts of 9.9, 10.1, and 8.1 log cfu/g respectively [49]. Enterobacteriaceae were <1 to 3.5 log cfu/g. The pH was 3.92±0.14. During the traditional production of borde with its four phases, the proportions of ingredients and cooking temperature were measured. Development of pH, titratable acidity, microbial load and mash temperature were monitored at 6 h intervals.

The initial pH of 6.01 fell to 3.84 at end of Phase I. However, the pH increased at the start of Phase II, III and IV fermentations due to addition of malt and/or unmalted cooked ingredients and then decreased to below pH 4.0 at the end of each phase. During Phase I, EB increased from 5.1 to 7.7 log cfu/g at 24 h, but were not detected after 48 h. AMC, LAB and yeasts increased from their initial 6.5, 5.3 and 4.5 respectively to 10.5, 10.6 and 7.5 log cfu/g at end of Phase I. The AMC of cooked ingredients were 4.6-4.9 log cfu/g, while Enterobacteriaceae, yeasts and LAB were not detected. After mixing the cooked ingredients and malt, the AMC, LAB and yeasts increased from 7.1, 6.3 and 5.4 at Phase II to 10.5, 10.5 and 8.6 log cfu/g in borde, respectively. Enterobacteriaceae decreased from 5.2 to <1 log cfu/g at Phase II and were not detected in borde. The major roles of Phase I, II, III and IV are production of an acidic fermented mass, bulk starter production, main and corrective fermentations, respectively [49].

2.4. Traditional Fermented Meat Products

2.4.1. Sausage fermentation

Sausages are essential parts of foods in many regions of the world. Coming to our country, Ethiopia, Sausage production has only a recent history. Traditional sausage (wakalim) is the most popular fermented food product in Harari, eastern part of Ethiopia. Its preparation relies on natural fermentation with ingredients as the main source of inocula. The preparation has four-steps that include the preparation of a casing, mincing of meat, stuffing and fermentation. Sausage fermentations are characterized by the succession of microbial groups in the course of fermentation. Although several groups are involved in the initiation of fermentation, only those tolerant to acids and metabolites generated during fermentation survive and dominate the final microflora. In naturally fermenting beef sausage, raw meat yields LAB in low numbers. However, the lactic flora rapidly dominates the fermentation because of the anaerobic environment generated during fermentation [42].

Gram-negative bacteria were under detectable level after day 4 of fermentation. But Staphylococci were detected at low levels (around 4 log cfu/g) until the end of fermentation. Thus, LAB dominated the flora at the end of fermentation. Different species of *Lactobacillus* and *Pediococcus* commenced the fermentation and the lactic flora was finally dominated by *L. plantarum* and *P. pentosaceus.* The pH of the fermenting wakalim dropped from 5.5 ± 0.22 to 4.1 ± 0.19, while the titratable acidity increased from 0.09 to 0.6% in the course of fermentation. Moreover, moisture content of the fermenting wakalim dropped from 66.5% ± 2.12 to 22.0% ± 0.71 during the 6 days of fermentation. The mean pH values of retail dry sausages ranged from 6.09 to 6.33 and moisture content values ranged from 35 to 41% [44].

2.5 Traditional Fermented Condiments

2.5.1. Awaze fermentation

It is known that, fermented food, beverage and condiment products are commonly produced throughout the world. Some fermented products produce strong flavor such kind of product is not consumed alone, but is added as a condiment to make the food more tasty and enjoyable. In general, different countries of Africa protein-rich food ingredients are often fermented to make condiments. Siljo, awaze and data are among the traditional fermented condiments in Ethiopia and are consumed with other items on the basis of their desired aromas and flavors. Therefore, these condiments result from the microbial fermentations of vegetable-spice mixtures [44].

The main substrates in awaze are red sweet pepper (*C. annum*), garlic (*Allium ursinum*) and ginger (*Zingiber officinale*) with which some proportions of different spices are added. Awaze is commonly known in the north and central Ethiopia and is often consumed with sliced raw or roasted meat and other traditional pancakes. While the microbiology and biochemical properties of several other traditional Ethiopian fermented foods and beverages have been studied there are no reports on the fermentation of awaze, indigenous Ethiopian condiment [15].

On the other hand LAB were enumerated and isolated from traditional fermented awaze. According them, a total of 87 LAB strains were isolated from awaze sample. Therefore, the isolates were grouped to different genera with their respective number: *Lactobacillus* (52), *Leuconostoc* (1), *Pediococcus* (27) and *Lactococcus* (7). In line with this, based on their glucose fermentation profile, the isolates were grouped as homofermentative and heterofermentative. However, the count of LAB for an awaze sample was (9.8 log cfu/g) [49].

2.5.2. Fermentation of siljo

Siljo is one of the traditional fermented condiments of Ethiopia made up of safflower (*Carthamus tinctorius*) extract and faba bean (*Vicia faba*) flour [43]. The black mustard powder, which is added after cooking the mixture of the safflower and faba bean, helps as source of starter microorganisms [48]. The fermented product has protein and fat content of 28 and 25%, respectively, with improved protein availability and concentration as a result of fermentation [46]. The heating step in siljo may be essential in decreasing the level of contamination, but addition of plant materials, for flavoring purposes, to the heated gruel during the process of fermentation, the frequency of serving, and hygienic quality of handlers are factors that contribute to the exposure of siljo to pathogens. Siljo is consumed usually during the long fasting periods when people consume no fatty food of animal origin that may prevent the proliferation of the pathogens [49].

Siljo was made to ferment naturally and the count of LAB reached 9.9 log cfu/ml on day 5. The pH dropped from an initial value of 5.8–4.65 during this time. The lactic acid flora was dominated by *Leuconostoc* spp. At ambient temperature storage (18 to 22°C), the product spoiled on day 16. The spoilage was caused by *Bacillus* spp. At refrigerated storage (4°C), however, the count of *Bacillus* spp. was below detectable limits (<1 log cfu/ml) until the end of experiment on day 16. When *Salmonella Typhimurium* DT 104 was inoculated into the fermenting gruel at low initial levels, the count decreased steadily and the test strain was not detected by enrichment on day 5. At higher initial inoculum level (5.5 log cfu/ml), complete elimination was observed on day 7. In a non-fermenting control gruel, count of the test strain increased by about 3 log units on day 7 [50].

2.5.3. Datta fermentation

There are many traditional condiments in different parts of the world produced by microbial fermentations. Such traditional condiments are used as taste enhancers in many traditional dishes. The majority of these fermentations are accompanied by certain biochemical changes of nutritional importance. Datta is among the traditional fermented condiments mainly in the southern parts of Ethiopia and are consumed with other items on the basis of their desirable aromas and flavors. It is results from the microbial fermentations of vegetable-spice mixtures. But the major substrate in the making of datta is the small chili pepper (*C. frutescenc*) at its green stage. Datta was also prepared following traditional methods. The small green pepper together with its seeds was carefully washed and cut into pieces. Garlic and ginger, in small proportion, were peeled, washed and cut into small pieces [49].

The homolactic LAB started and dominated the fermentation for the first 2 days and the heterolactics took over thereafter. Datta fermentations were accompanied by declining pH and increasing titratable acidity. *Salmonella Typhimurium* was repressed during both fermentations within 48 h. Datta had low initial contents of available protein and reducing sugars and did not show marked differences throughout the fermentation [46].

3. CONCLUSION

Fermentation is one of the best efficient techniques of producing and preserving foods. It is fairly a low-energy requiring conservation technology that improves shelf life of food products. In cases fermentation is important to obtain a certain food, the microorganisms present on the raw ingredients or in the containers spontaneously take care of the process. In most of these products the fermentation is spontaneous and involves different microorganisms.

Generally, clear understanding of the procedures involved in the process of making of the traditional fermented food and beverage products could help to design mechanism for production of an industrially based finished product. And it has the advantage of reducing wastage during processing, which is significant at household level. In line with this, eating fermented foods has a beneficial health effect for human beings as well as animals.

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