Int.J.Curr.Res.Aca.Rev.2019; 7(5): 13-27

International Journal of Current Research and Academic Review

ISSN: 2347-3215 (Online) Volume 7 Number 5 (May-2019)

Journal homepage: http://www.ijcrar.com

doi: https://doi.org/10.20546/ijcrar.2019.705.004

Review on Ethiopian Traditional Fermented Foods, its Microbial Ecology and Nutritional Value

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Abstract

Fermented foods and beverages, whether of plant or animal origin, play an important role in the diet of people in many parts of the world. Fermented foods not only provide important sources of nutrients but have also great potential in maintaining health and preventing diseases. Lactic acid bacteria and yeasts are the major group of microorganisms associated with traditional fermented foods. Yoghurt is one of a fermented dairy product, having several health benefits. Yoghurt starter culture consists of a blend of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp *Bulgaricus*. Yoghurt is mainly of two types i.e. set yoghurt and stirred yoghurt. Yoghurt properties can be enhanced by the addition or treatment with various additives. Alternative methods to improve quality of low-fat yoghurt become an area of considerable research interest. Soymilk and maize steep water were used as alternative raw materials to cow milk and commercial starter, respectively, for production of yoghurt. 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. Injera is made using teff, a tiny, round grain that flourishes in the highlands of Ethiopia. While teff is very nutritious, it contains very little gluten (which makes it poorly suited for the making of raised bread). However, it still takes advantage of the inherent properties of yeast, as fermentation lends it an airy, bubbly texture. Injera may be made solely from teff, as it most commonly is in Ethiopia, or it may be made using a combination of teff, wheat, and other substitute flours. Wakalim is a spiced traditional Ethiopian fermented beef sausage. Early stages (0–12 h) of wakalim fermentation were dominated by lactic acid bacteria and aerobic mesophilic bacteria including staphylococci and members of Enterobacteriaceae. Gram-negative bacteria were below detectable level after day 4 of fermentation. Tella is popular Ethiopian traditional beverages, which is made from diverse ingredients. 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 annually in households and drinking houses in Addis Ababa alone. Some of them consider as local beer. It is traditionally drunk on major religious festivals, saint's days and weddings.

Article Info

Accepted: 20 April 2019
Available Online: 20 May 2019

Keywords

Ayib, Ethiopian Traditional Fermented Foods, Injera, Tella, Wakalim

Introduction

Fermented foods and beverages, whether of plant or animal origin, play an important role in the diet of people in many parts of the world (Kabak, 2011). Fermentation was evolved as a preservation or prevention technique and during lean periods to counter spoilage of food products. It is one of the oldest and most economical methods for producing and preserving foods. In addition to preservation, fermented foods can also have added benefits of enhancing flavour, increased digestibility, and improving nutritional and pharmacological values (Satish Kumar *et al.*, 2013). Fermented foods not only provide important sources of nutrients but have also great potential in maintaining health and preventing diseases. Lactic acid bacteria and yeasts are the major group of microorganisms associated with traditional fermented foods. Many different types of traditional fermented foods and beverages are produced at household. These include fermented milks, cereal-based fermented food, and non-alcoholic beverage, fermented fruits, and vegetables, and fermented meat (Kabak, 2011). Traditional fermented foods are popularly consumed and form an integral part of our diet since early history. It can be prepared in the household or in cottage industry using relatively simple techniques and equipments (Satish Kumar *et al.,* 2013).

Fermentation technologies play an important role in ensuring the food security of millions of people around the world, particularly marginalised and vulnerable groups (Mejia, 2011). Fermentation is a process that has been used by humans for thousands of years, with major roles in food preservation and alcohol production. Fermentation is primarily an anaerobic process converting sugars, such as glucose, to other compounds like alcohol, while producing energy for the microorganism or cell. Bacteria and yeast are microorganisms with the enzymatic capacity for fermentation, specifically, lactic acid fermentation in the former and ethanol fermentation in the latter. Many different products around the world are a result of fermentation, either occurring naturally or through addition of a starter culture. Different bacterial and yeast species are present in each case, which contribute to the unique flavors and textures present in fermented food (Chilton *et al.*, 2015). The main purpose of this review is to access available information on traditional fermented food practiced in Ethiopia starting from available journal information.

Fermented dairy products (Yoghurt, Cheese)

Yoghurt

Yoghurt is a fermented dairy product, having several health benefits. Yoghurt starter culture consists of a blend of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp *Bulgaricus*. Yoghurt is mainly of two types i.e. set yoghurt and stirred yoghurt. Yoghurt properties can be enhanced by the addition or treatment with various additives. Alternative methods to improve quality of low-fat yoghurt become an area of considerable research interest. Lactic acid can be produced by the yoghurt. Yoghurts that have past their ‘best before’ date constitute a waste that has to be environmentally treated. It can be used as a source for lactic acid production by *Lactobacillus casei*. Yoghurt can be supplemented with various useful ingredients. Addition of herbs or their active components like oils could be an effective strategy to improve functionality of milk and milk products with respect to the health benefits, food safety and biopreservation. Recent developments in this regard have been thoroughly discussed (Priyanka Aswal, 2012).

Yoghurt is a functional food. The functional food includes probiotics, prebiotics and synbiotics. Probiotics can be defined as “live microbial feed supplements that beneficially affect the host animal by improving its intestinal microbial balance” (NJ, 2005). Prebiotics as “non-digestible food ingredient that beneficially affects the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon”. Synbiotic is a combination of probiotics and prebiotics that “beneficially affects the host by improving the survival and the implantation of live microbial dietary supplements in the gastro-intestinal tract by selectively stimulating the growth and/or by activating the metabolism of one or a limited number of health promoting bacteria” (DB, 2000).

Soymilk and maize steep water were used as alternative raw materials to cow milk and commercial starter, respectively, for production of yoghurt. The cow milk used was both Fresh milk and dried powdered milk (DANO). The cost of production of the yoghurt samples as well as their chemical, microbial and organoleptic properties was compared with that of the commercially available yoghurt (FAN MILK). There was no significant difference ($P<0.05$) in the protein content of soymilk yoghurt (either fermented with commercial starter or maize steep water) and that of the dried powdered milk yoghurt fermented with maize steep water. Soymilk yoghurt fermented with commercial starter contained the highest moisture, the least carbohydrate and the least total solid, 94.07%, 0.81% and 5.89 g/100 g, respectively. The commercial yoghurt recorded the highest phosphorous and calcium 59.09 and 49.60 ppm, respectively. There was no significant difference ($p<0.05$) in the total viable count of soymilk yoghurt fermented with commercial starter and soymilk yoghurt fermented with maize steep water. Soymilk yoghurt fermented with maize steep water compares well with the other yoghurt samples organoleptically and costs less to produce (Farinde *et al.,* 2008).

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(F, 1998).

In a study on the microbiological quality of ayib(A, 1990), samples collected from an open market in Awassa had counts of mesophilic aerobic bacteria (AMB), yeasts and enterococci of 108, 107 and 107 cfu/g, respectively. 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 (Anteneh and Tetemke, 2011).

Further analysis of ayib micro flora revealed that bacterial and yeast counts did not relate with pH value of ayib samples. It is clear that ayib samples with pH greater 4.0 contained more bacterial groups than those with pH less than 4.0. The Gram-positive rods dominated the aerobic mesophilic bacterial flora, being the most abundant. Enterobacteriaceae and *Pseudomonas* species constituted the bulk of the Gram-negative rods. The count of LAB was around 106 cfu/g and *L. fermentum* and *L. plantarum* dominated the flora. Though the low pH of ayib inhibits the growth of many food-borne pathogens, higher numbers of LAB and yeasts are not desirable in ayib. A considerably lower pH due to the activity of LAB may result in a too sour product with a low sensory quality (Anteneh and Tetemke, 2011).

The main ingredient in cheese is milk. Cheese is made using cow, goat, sheep, water buffalo or a blend of these milks. The type of coagulant used depends on the type of cheese desired. For acid cheeses, an acid source such as acetic acid (the acid in vinegar) or gluconodelta-lactone (a mild food acid) is used. For rennet cheeses, calf rennet or, more commonly, a rennet produced through microbial bioprocessing is used. Calcium chloride is sometimes added to the cheese to improve the coagulation properties of the milk. Flavorings may be added depending on the cheese. Some common ingredients include herbs, spices, hot and sweet peppers, horseradish, and port wine("Milk Facts Info," 2018).

The milk used for cheese production should be fresh, good quality and free from dirt and excessive contamination by bacteria. Older milk may impart an unpleasant flavour to the final product. Technical Brief: Dairy processing - an overview gives details of the methods needed to ensure that good quality milk is used. Cultures for cheese making are called lactic acid bacteria (LAB) because their primary source of energy is the lactose in milk and their primary metabolic product is lactic acid. There is a wide variety of bacterial cultures available that provide distinct flavor and textural characteristics to cheeses.

Starter cultures are used early in the cheese making process to assist with coagulation by lowering the pH prior to rennet addition. The metabolism of the starter cultures contribute desirable flavor compounds, and help prevent the growth of spoilage organisms and pathogens. Typical starter bacteria include *Lactococcus lactis* subsp. *lactis or cremoris*, *Streptococcus salivarius subsp. thermophilus, Lactobacillus delbruckii subsp. bulgaricus* and *Lactobacillus helveticus*.

Adjunct cultures are used to provide or enhance the characteristic flavors and textures of cheese. Common adjunct cultures added during manufacture include *Lactobacillus casei* and *Lactobacillus plantarum* for flavor in Cheddar cheese, or the use of *Propionibacterium freudenreichii* for eye formation in Swiss. Adjunct cultures can also be used as a smear for washing the outside of the formed cheese, such as the use of *Brevibacterium linens* of gruyere, brick and limburger cheeses.

Yeasts and molds are used in some cheeses to provide the characteristic colors and flavors of some cheese varieties. Torula yeast is used in the smear for the ripening of brick and limberger cheese. Examples of molds include *Penicillium camemberti* in camembert and brie, and *Penicillium roqueforti* in blue cheeses.

Nutritional value of cheese

Cheese can be the perfect component to complete your meal or snack. A few ways to use cheese are for cheese plates with grapes, egg white and cheddar cheese breakfast burritos, Swiss cheese and ham sandwiches, Greek salads with feta cheese, pasta with Parmesan cheese and chicken baked with mozzarella cheese. Cheese is a source of many essential nutrients, including high-quality protein, and it can be a regular part of a healthy, balanced diet (Birhanu Gashe, 1985).

Caloric content

An ounce of most kinds of cheese has 95 to 120 calories, although feta cheese is slightly lower, with 75 calories per ounce. High-calorie foods, such as full-fat cheese, can lead to weight gain. Monitor your portion sizes and eat them with lower-calorie foods to avoid this. Try shredded Swiss cheese as a topping for onion soup, grated Parmesan in an omelet made with egg whites and a green salad with diced apple and blue cheese.

Fat in cheese

An ounce of cheddar cheese has 9.4 grams of fat and 6 grams of saturated fat, and an ounce of brie cheese 7.8 grams of fat and 4.9 grams of saturated fat. Saturated fat raises your cholesterol levels, and healthy adults on a 2,000-calorie diet should limit consumption to 20 grams per day. Cheese is among the top sources of solid fats in the typical American diet, according to the 2010 Dietary Guidelines for Americans. Choose reduced-fat dairy products to limit your consumption of saturated fat and calories. An ounce of low-fat cheddar cheese has 2 grams of total fat and 1.2 grams of saturated fat.

Calcium in cheese

An ounce of cheddar cheese provides 200 milligrams of calcium, or 20 percent of the daily value based on a 2,000-calorie diet. Soft cheese has less calcium per serving, with 52 milligrams in a 1-ounce serving of Brie cheese. Calcium is necessary for maintaining strong bones. Eat your cheese with a source of vitamin D to improve your body's ability to absorb calcium from the cheese. Choose cheese fortified with vitamin D or have a pizza with cheese and anchovies.

Sodium in cheese

An ounce of regular cheddar cheese has 247 milligrams of sodium. Most cheese contains sodium because of the salt added during the cheese-making process. Not counting dishes with cheese such as pizza and pasta dishes, cheese provides 3.5 percent of the total amount of sodium in Americans' diets, according to the 2010 Dietary Guidelines for Americans. A high-sodium diet can increase your risk for heart disease, kidney disease and stroke, and healthy individuals should limit daily intake to 2,300 milligrams per day. An ounce of reduced-sodium cheese has only 4 milligrams of sodium (Gashe, 1985).

Fermented cereal products (Injera Fermentation)

Injera is made using teff, a tiny, round grain that flourishes in the highlands of Ethiopia. While teff is very nutritious, it contains very little gluten (which makes it poorly suited for the making of raised bread). However, it still takes advantage of the inherent properties of yeast, as fermentation lends it an airy, bubbly texture. Injera may be made solely from teff, as it most commonly is in Ethiopia, or it may be made using a combination of teff, wheat, and other substitute flours, as it sometimes is in the United States, yielding a formative batter which is usually slightly thinner than conventional North American pancake mix. Regardless of the ways in which it is modified around the world, teff-bearing injera constitutes a unique delicacy, and one for which the worldwide demand increases each year (Tesfaye, 2017).

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 (Tesfaye, 2017).

Preparation procedures

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 (CSA, 2008). 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 (Tesfaye, 2017).

Involved microorganisms

Tef injera, a pancake-like acidic food is prepared from fermented tef (Eragrostis tef), flour. A complex group of microorganisms is involved in the fermentation. Fermentation is initiated by members of the Enterobacteriaceae. Their activities during the first 18 hr of fermentation reduce the pfi of the dough to about 5.8. They are then succeeded by *Leuconostoc mesenteroides* and *Streptococcus faecalis*.

As the pH is further reduced to about 4.7, *Pediococcus cerevisiae*, *Lactobacillus brevis*, *Lactobacillus plantarum* and Lactobacillus fermentum become the predominating flora and remain so until the fermentation is terminated at 72 hr. These lactic acid bacteria are responsible for the acidic characteristics of the dough. Yeasts only appear in significant numbers at a later stage of the fermentation (Gashe, 1985).

Nutritional value

Spongy, flat and dotted with tiny holes, injera is a traditional African flatbread served in both Ethiopia and Eritrea. Injera is served alongside various meat and vegetable stews and is used to scoop up pieces of food with your hands, as well as soak up the sauces part of every Ethiopian and Eritrean meal. Made with teff flour, a short fermentation period gives the bread its distinctive sour taste (Michelle, 2017) (Table 1).

Macronutrients

A single serving of injera bread has 379 calories. Because it is cooked in a pan with oil, there are 1.2 grams of fat per serving, although it has minimal saturated fat, with only 0.2 grams per serving. When cooking injera, use a mild-tasting cooking oil like vegetable or grapeseed oil. A single serving of injera has almost no sugar and almost 12 grams of protein.

Dietary fiber and sodium

A single serving of injera has 868 milligrams of sodium, and 4.2 grams of dietary fiber. According to Colorado State University, most Americans routinely get too much sodium and not enough dietary fiber in their daily diets. The upper limit of sodium per day is 2,300 milligrams but only 1,500 milligrams for people who are over 51 years old, who have heart disease or are African-American. In turn, between 21 and 38 grams of dietary fiber is the dietary reference intake per day for adult men and women.

Minerals in Teff

Teff — the tiny, poppy seed-sized grain used to make injera — is rich in a variety of nutrients, providing those from harsh growing conditions — flooding and droughts, high altitudes — a source of many essential vitamins and minerals. A one-quarter-cup serving of teff has 3.68 milligrams of iron, 87 milligrams of calcium, 206 milligrams of potassium, 207 milligrams of phosphorous, 89 milligrams of magnesium and 1.75 milligrams of zinc per serving. All these essential minerals help your body with various functions, including transporting oxygen throughout your body, in the case of iron; maintaining your heart's electrical activity; in the case of potassium; and making it possible for you to taste and smell, in the case of zinc.

Vitamins in Teff

Teff is rich in a number of essential vitamins, including many from the vitamin B group and vitamins A and K. A one-quarter-cup serving of teff has almost 0.2 milligrams of thiamin, 0.13 milligrams of riboflavin, 1.6 milligrams of niacin and 0.2 milligrams of vitamin B-6. It also has 4 international units of vitamin A and 0.9 micrograms of vitamin K. Members of the vitamin B complex provide support for your immune system, and help you process carbohydrates into glucose. Vitamin A is essential for eye health, as well as being a natural antioxidant, protecting your body from damage from free radicals, created when your body digests food or encounters environmental toxins, such as exhaust fumes. Toxins and free radicals can cause cell damage and death, increasing your risk of heart disease and cancer. Vitamin K is known as the clotting vitamin, essential for blood coagulation (Michelle, 2017).

Fermented meat (Wakalim)

Wakalim is a spiced traditional Ethiopian fermented beef sausage. Early stages (0–12 h) of wakalim fermentation were dominated by lactic acid bacteria and aerobic mesophilic bacteria including staphylococci and members of Enterobacteriaceae. Gram-negative bacteria were below detectable level after day 4 of fermentation. Staphylococci were detected at low levels (around 4 log cfu/g) until the end of fermentation. Lactic acid bacteria grew and dominated the flora at the end of fermentation. Various species of *Lactobacillus* and *Pediococcus* initiated the fermentation and the lactic flora was finally dominated by Lb. plantarum1 and Ped. pentosaceus1. 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 (Table 2). Molecular characterization, using 16S rDNA partial sequence analysis and repetitive sequence-based polymerase chain reaction, of the isolates confirmed some of the earlier phenotypic identification made based on API carbohydrate fermentation profile. Some of the strains were, however, identified as different species of the same genus or entirely different genus. The findings of this study are the first of their kind from traditional Ethiopian fermented sausage and could have paramount importance as a baseline data for large-scale production of the traditional product using defined starter cultures. Moreover, the strains characterized in this study could be exploited as potential starter cultures for the commercialization of wakalim (Ketema Bacha, 2010).

Preparation procedures

First the meat and a few heads of onion are cut into small pieces, and put into a vessel, where they are mixed with several spices - cardamom, coriander. cinnamon, cloves, chamomile, black pepper, cumin-seeds, and hurdinci. These spices, ground into powder and with the addition of a measured quantity of salt and red-pepper, are mixed with the meat so that every piece of meat is well covered with the powder. Next the tube or skin from intestine, called maraci, is prepared. Usually the small intestine of an ox makes the tube. This undergoes a series of washings and cleanings. First the tube is turned inside out and washed with ash in order to remove the dirt and the slippery mucous from its wall. After this it is put into a vessel of pure water and cleaned. Here the first washing ends. The second washing is made with soap and water, and again it is put into a vessel with fresh water. The third and the last washing is with lemon and salty water. By this time the tube has become white membrane; it is turned right side out and tied at one end, blown up with the mouth and the other end tied to make a kind of bladder. This inflation causes the tube to coil automatically. It is twisted around a cane and exposed to the sun to dry for about one hour. After the skin is completely dry it is cut into small pieces of about 9 inches long, which is the length of an average wakalim. Then the spiced meat is forced into the tube with the finger; when the skin is quite full it is bent into a U-shape, and the two ends are twisted together to form a closing. Sometimes while the meat is being inserted, the tube breaks due to old age or to too much drying. To avoid this the tubes are usually damped beforehand by inserting them into the meat. When all the meat has been used up and the wakalim are ready, they are taken to the kitchen and strung on a rope stretched a little way above the hearth so that they receive only the heat and not the direct flame, otherwise the tube will crack. When sufficiently warm the tubes are pricked here and there. After some time moisture oozes from them and falls drop by drop. This process of drying the wakalim does not end in one day. It has to be repeated for three or four days. Usually they are brought to the kitchen when the fire is set for the preparation of lunch or dinner, and taken back after that, or else the kitchen is locked. These precautions are necessary as the young people love wakalim, and would never miss the opportunity to steal one or two, especially during a marriage feast. Now the wakalim which has passed the stage of drying is ready to be eaten. It is eaten either cooked or uncooked. If it is for an official meal it is dipped into a dish of soup and cooked for a few minutes. But if not an official meal it may be roasted or taken raw. The young people prefer it uncooked. It is believed that the wakalim can keep for a long time, at least for several months, provided proper care it taken of it. Firstly to avoid dampness it is advisable to hang it on a rope. Secondly it should be carried to the kitchen and smoked once every one or two weeks. This action prevents it from spoiling. Consequently it will keep for a long time. It is for this reason that wakalim is considered as the best provision for pilgrims who go to the hagg. Lastly it should be made clear that wakalim is not an every-day food, but is prepared or served on notable occasions, such as the marriage feast, Ramadan fast, Arafa feast and for the pilgrims. It is essential at a marriage feast when it is prepared in large quantity. At every meal to which the bride is invited some wakalim as a customary rule should be offered. Also it is impossible to think of a meal that is sent, as is the custom, to the newly-married pair, without a few wakalim added as a compliment (Ahmed, 2018).

Beverages (Tella, Shamita, Borde)

Tella

Tella is popular Ethiopian traditional beverages, which is made from diverse ingredients. 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 annually in households and drinking houses in Addis Ababa alone (Shale, 1991). 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(Fite A, Tadesse A, Urga K, 1991). 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 (Vogel, 1983). Generally, tella is brewing 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.

Preparation procedures

The way of making tella varies among the ethnic groups and depends on traditional and the economic situation. The clay container (insera) is washed with grawa (*Vernonia amygdalina*) and water numerous times and then smoked with wood from weyra (*Olea europaea* subsp. *cuspidate*) for about 10 min, in order to get it as clean as possible. Germinated grain of barley, or corn, or wheat (bikil), bought in the local market or prepared at home, are dried and milled. For making bikil, the grains are moistened in water and the moist grains are placed between fresh leaves, left to germinate for 3 days and after that dried. Gesho (*R. prinoides*), local hops, is available dried in the local market. The leaves of gesho are separated from the stem and dried again in the sun for about ½ h and then pounded. The ground gesho leaves are placed in a clay container with water and left to ferment for 2 to 3 days. Gesho is responsible for the bitter taste of tella. It is also thought to be the source of various chemicals (Shale, 1991; Kebede, 2006). It is assumed that gesho maintains acidic pH during tella fermentation so as to modify the nature of the mash and impedes the growth of unwanted microorganism (Kebede, 2006).

Some of the grains intended for tella preparation are toasted and milled, and then mixed with water and baked on the mitad to prepare what is known as kita (a thin, 5 to 10 mm thick, pancake- like bread). This kita, broken into small pieces, part of the milled bikil and the pounded gesho stems are added to the water and allowed to ferment for 1 to 2 days. The rest of the flour is toasted on mitad, sprinkled with water and toasted until dark brown to form what is known as enkuro. This mixture of enkuro, the rest of the germinated grains (bikil), some gesho, and water are added to the container. The mixture is kept covered overnight, after which more water is added and the container is kept sealed for 5 to 7 days, until when the beverage is ready. Tella can be kept for 10 to 12 days. According to Shale and Gashe (1991), who made a detailed study of tella fermentation, there are numerous recipes for preparing tella and it appears as if every housewife has her own version of the recipe. The fermenting organisms of tella are composed of *S. cerevisiae* and Lactobacillus spp. Increase in ethanol content [2.2 to 5% (v/v)] is directly associated with growth in the population of yeasts and decrease in reducing sugar and total carbohydrate. The pH of tella is in the range of 4.5 to 4.8.

For tella considered to be a good quality, the final ethanol content is in the range of 2 to 8% (v/v) and pH is 4 to 5. The biochemical changes, the microorganisms involved in the fermentation and those which bring about necessary and unwanted changes in the process of tella making are described (Shale, 1991). According to the report, the fermentation process of tella is divided into four phases. The first occurs in the original mixtures of ingredients, and the second and third phases occur after successive additions of more carbohydrate materials. The three main carbohydrate materials are mentioned to be bikil, kitta and enkuro. The latter phase is where acidification takes place, which is actually not desirable. Maximum ethanol production occurs during the third phase and at the beginning of the fourth phase. Shale and Gashe (1991), reported that 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). 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 by Fite *et al.*, (1991). The mean values for methanol, fuel oil, and ethanol were found to be 35 ppm, 66 ppm, and 3.6%, respectively.

Shamita

Shamita is another traditional beverage of Ethiopia, which is low in alcohol content, made by overnight fermentation of mainly roasted barley flour and, consumed as meal-replacement (Ketema and Tetemke, 1999). Shamita is a widely consumed beverage in different regions of Ethiopia. It has a thick consistency and most people who cannot afford a reasonable meal consume it as meal replacement. It is produced by fermenting roasted barely overnight. Malt is not commonly used in shamita fermentation, although local shamita brewers in Addis Ababa use it frequently, and starch is the only principal fermentable carbohydrate.

The microbes liable for fermentation are mostly from back slopping using small amount of shamita from a previous fermentation as well as from the ingredients and equipment. Ready to consume shamita has a high microbial count made up of mostly LAB and yeast. These microorganisms make the product a good source of microbial protein. However, shamita has poor keeping quality because of these high numbers of live microorganisms and becomes too sour about four hours after being ready for consumption (Mogosie, 1995).

According to Anteneh *et al.*, (2011c), study on antagonism of LAB against foodborne pathogens during fermentation and storage of borde and shamita, pure LAB cultures decreased in average the number of test pathogens by 4 log cycles at 24 h during fermentation shamita. And also the mixed LAB cultures decreased the number of pathogens by 5 log units after 24 h of fermentation shamita. Coming to storage of shamita at ambient temperature, the test pathogens were reduced by 4 log units at 12 h and totally eliminated at 24 h. Therefore, they strongly suggest that the isolates are possible candidates for the formulation of starter cultures that can be used to produce safe and bioprotective products (Anteneh and Tetemke, 2011).

According Mogessie and Tetemke, 1995, the pH of ready to consume shamita in Awassa town was reported to be 4.2 and the product had high microbial counts (106 to 107 cfu/ml) consisting mainly LAB and yeasts. In a microbiological study of shamita fermentation, In other case Ketema *et al.*, (1999), reported that all ingredients and the clay jar rinse water had large numbers of aerobic mesophilic bacteria (>104 cfu/ml) mainly consisting of Bacillus and Micrococcus spp. Barley malt contributed most of the LAB and yeasts, which were important to the fermentation. They dominated the fermentation flora reaching final counts of 109 and 107cfu/ml, respectively.

In line with this, according to Negasi *et al.*, 2017, study on in vitro characteristics of lactic acid bacteria isolated from traditional fermented shamita and kocho for their desirable characteristics as probiotics, the genera *Lactobacillus, Leuconostoc, Pediococcus* and *Lactococcus* were present in shamita. And also Lactobacillus isolates were the most frequently isolated groups from shamita.

Borde

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 (Kebede *et al.*, 2002).

Borde is produced by natural fermentation of a diversity of locally available cereal ingredients. 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. 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.

The last portion of fermented grits from phase I (72 h) was added into a pan containing a boiling mixture of whole grains of sorghum and water, further boiled into a very thick porridge with continuous stirring and then cooled. The gelled porridge was added to the fermented difdif, along with a small amount of additional malt. After a thorough mixing, the thick brown mash was sieved through a wonnfit (about 1 mm pore size). The residues were then wet milled using traditional grinding stones and sieved 2 times. The filtrates were pooled and poured back into the same rinsed insira and the fermentation was then continued for 6 h (after the addition of porridge). Actively fermenting effervescent borde was then ready for consumption. The production of borde was repeated three times at room temperature (20- 23°C) and the results are average of the triplicates. In addition, preliminary experiments were carried out to compare the following: (1) the 48 to 72 h fermentation with 24 to 48 h at Phase I; (2) earthenware pot with plastic, metal and glass jars; (3) substitution of maize grits and sorghum grains with flour; and (4) roasting of enkuro with baking of kita (flat bread) (Fig. 1 and 2).

Table.1 Nutritional information of yogurt (Priyanka Aswal, 2012)

Components	Value (per 100g)
Energy	257KJ
Carbohydrates	4.7g
Fat	3.3g
Protein	3.5g
Vitamin A equiv.	27 µg (3%)
Riboflavin (vit. B2)	0.14 mg (12%)
Calcium	

Table.2 Microbiological ecology of Awaze (Asnake, 2012)

Microbial groups	Log cfu/g (Mean±SD		
	Processor 1	Processor 2	Processor 3
Aerobic mesophiles	5.43±1.21^{a}	4.82±0.83^{a}	4.54±0.91^{a}
Enterobacteriaceae	3.44±1.46^{a}	1.89±1.01^{b}	2.17±1.14^{ab}
Coliforms	3.33±1.45^{a}	1.56±0.92^{b}	1.82±1.14^{b}
Enterococci	3.53±1.22^{a}	2.37±1.26^{b}	1.78±1.09^{ab}
Staphylococci	3.72±2.18^{a}	2.89±1.69^{a}	2.66±1.58^{a}
Lactic acid bacteria	6.19±1.89^{a}	5.98±1.59^{a}	4.86±1.23^{a}
Yeast	4.37±0.59^{a}	3.91±0.78^{a}	3.34±1.28^{a}

Means in rows followed by the same letters are not significantly different (P > 0.05). SD: Standard deviation.

Production of Different Types of Yoghurt

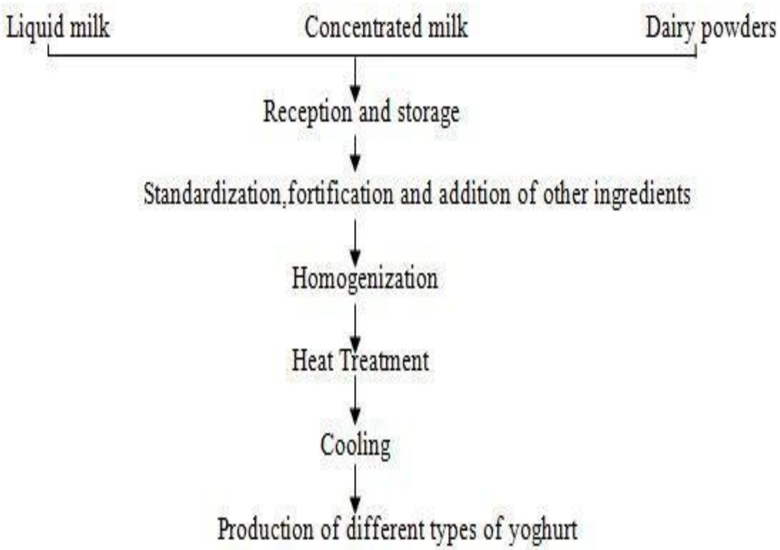


Figure.1 Processing of Yoghurt

Processing of Set and Stirred Yoghurt (Lucey, 2010)

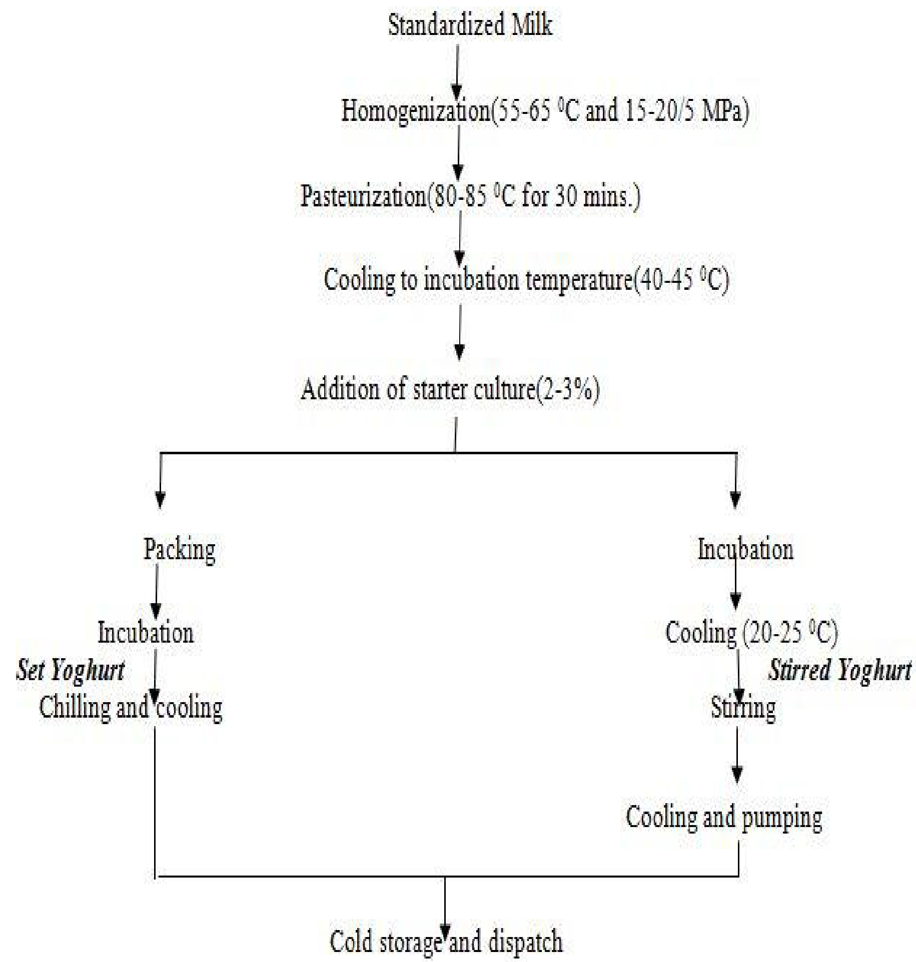
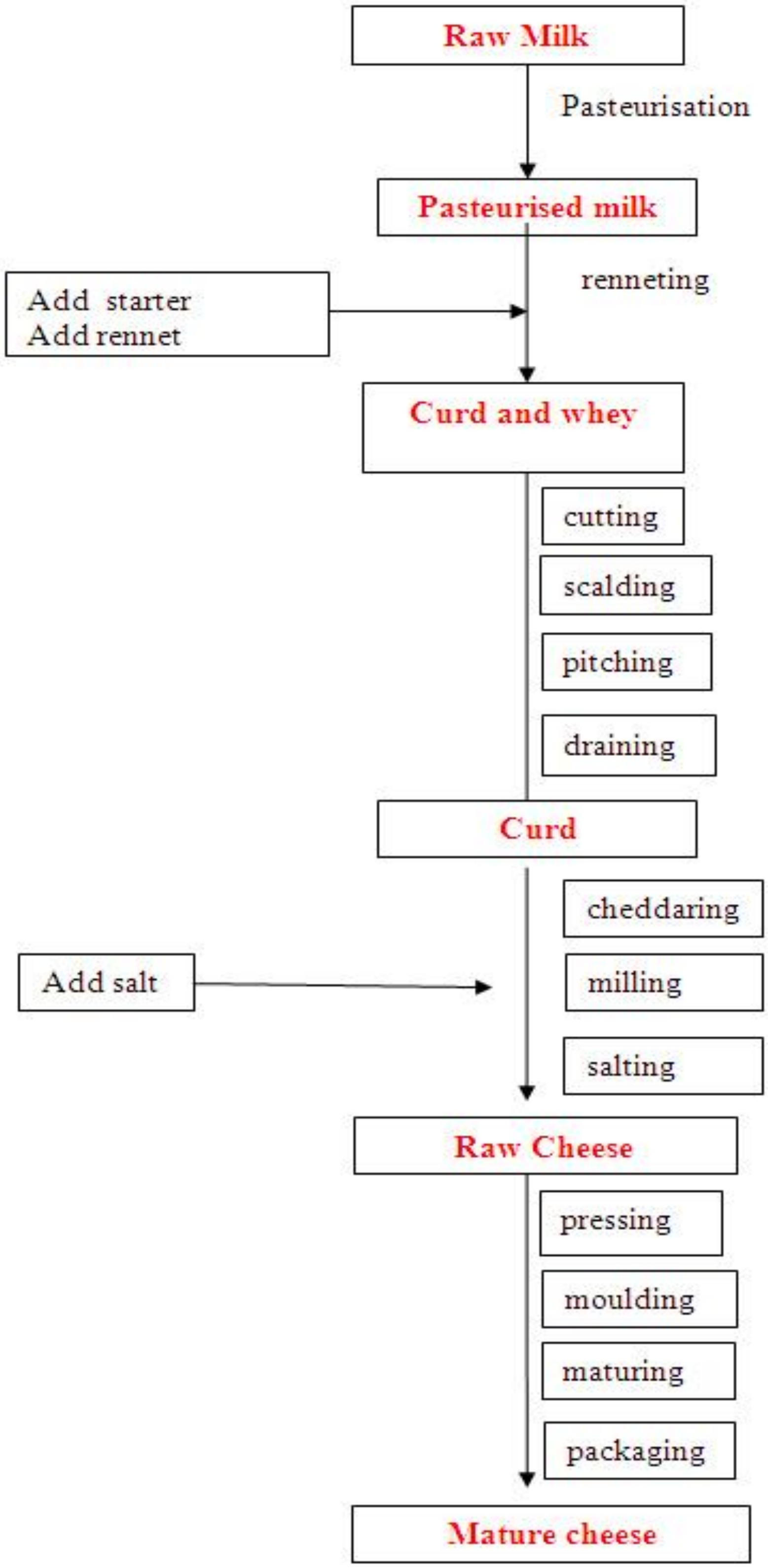
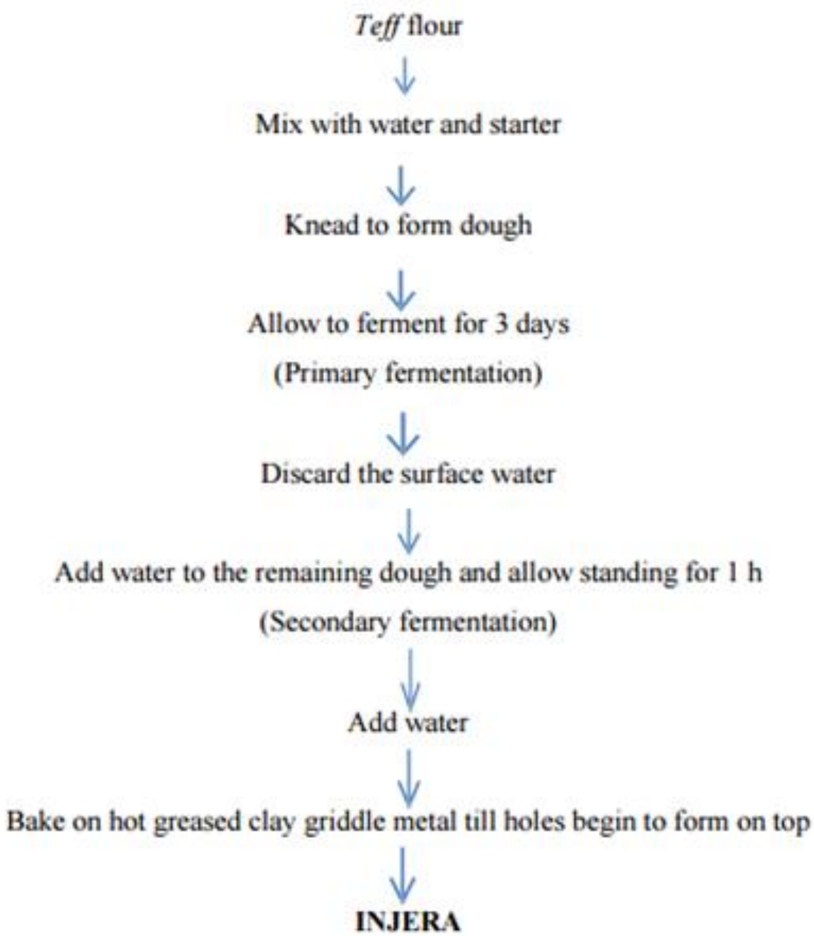


Figure.2 Processing of Set and Stirred Yoghurt (Lucey, 2010)

Flowchart.1 Preparation flowchart of cheese (“Milk Facts Info,” 2018)



Flowchart.2 Procedures of Injera Preparation (Gebrekidan, 1982)



According to Kebede *et al.*, (2002) report 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. 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.

Condiment (Awaze, Datta, Siljo)

Awaze

It is known that, fermented food, beverage and condiment products are commonly produced throughout the world. Some fermented products produce strong flavor such that the 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 (Hesseltine, 1980).

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 (Gashe, 1985; Ketema Bacha, 2009; Shale, 1991), there are no reports on the fermentation of awaze, indigenous Ethiopian condiment.

However, a study on fermentation of awaze indicated that the aerobic mesophilic microflora of the ingredients of awaze was dominated by Bacillus spp. (1.1×106 cfu/g) and LAB (4.5×104 cfu/g). The counts of AMB dropped during the fermentation period. LAB reached the maximum count of 5.9×109 cfu/g at day 4 and the count remained >108 cfu/g throughout the fermentation. The heterofermentative LAB dominated until day 3; thereafter, the homolactics dominated the fermentation. Yeasts appeared at day 6 and increased to 2.5×106 cfu/g. Hence, fermentation of awaze was accompanied by declining pH and increasing titratable acidity.

In addition to this, *Salmonella typhimurium* was repressed during the fermentation within 48 h. But awaze had low initial contents of available protein and reducing sugars and did not show marked differences throughout the fermentation (Ahmed and Tetemke, 2001).

On the other hand, Asnake and Mogessie, 2010, studied that 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).

Datta

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. The pepper, garlic and ginger were mixed with small amounts of fresh sweet basil and seeds of rue. The mixed ingredients were manually wet-milled on a flat smooth traditional stone-mill into a greenish paste. It was then transferred into a 500 ml screw-cap bottle to ferment at ambient temperature (20 to 25°C) (Tesfaye, 2017).

According to Ahmed *et al.*, 2001 study in datta fermentation, the count of AMB remained unchanged during the fermentation. LAB initiated the fermentation at a level of 7.1×104 cfu/g and reached 1.2×109 cfu/g at day 7. 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 (Ahmed and Tetemke, 2001).

Siljo

Siljo is one of the traditional fermented condiments of Ethiopia made up of safflower (*Carthamus tinctorius*) extract and faba bean (*Vicia faba*) flour(Mogosie A, 1995). The black mustard powder, which is added after cooking the mixture of the safflower and faba bean, helps as source of starter microorganisms (Mogosie, 1995; Zewdie and Urga, 1995). The fermented product has protein and fat content of 28 and 25%, respectively, with improved protein availability and concentration as a result of fermentation. 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 (Shin and Suzuki, 2002).

During the natural fermentations, the type of fermenting flora is determined by the initial flora of the ingredients. Thus, different workers have reported diverse microorganisms to be liable for the fermentation of siljo (Mogosie, 1995; Zewdie and Urga, 1995). In preparation of siljo, a volume of 1600 ml of siljo was made from safflower (*Carthamus tinctorius*), faba bean (*Vicia faba*) and black mustard powder. This was divided into 4 screw-capped bottles, each containing 400 ml of the gruel. The gruel was left to ferment naturally at ambient temperature. At around 32 h of fermentation, peeled garlic, ginger, Ethiopian caraway and rue leaves, about 2 g each, were added into each bottle and the fermentation was allowed to continue at ambient temperature.

According to Eden and Mogessie (2005), 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) (Tesfaye, 2017).

In conclusion, fermented foods and beverages, whether of plant or animal origin, play an important role in the diet of people in many parts of the world. Fermented foods not only provide important sources of nutrients but have also great potential in maintaining health and preventing diseases. Lactic acid bacteria and yeasts are the major group of microorganisms associated with traditional fermented foods. Yoghurt is a fermented dairy product, having several health benefits. Yoghurt properties can be enhanced by the addition or treatment with various additives. Alternative methods to improve quality of low-fat yoghurt become an area of considerable research interest. Soymilk and maize steep water were used as alternative raw materials to cow milk and commercial starter, respectively, for production of yoghurt. Ayib, a traditional Ethiopian cottage cheese, is a popular milk product consumed by the several local groups of the country. Injera is made using teff, a tiny, round grain that flourishes in the highlands of Ethiopia. While teff is very nutritious, it contains very little gluten (which makes it poorly suited for the making of raised bread). However, it still takes advantage of the inherent properties of yeast, as fermentation lends it an airy, bubbly texture. Injera may be made solely from teff, as it most commonly is in Ethiopia, or it may be made using a combination of teff, wheat, and other substitute flours. Wakalim is a spiced traditional Ethiopian fermented beef sausage. Tella is popular Ethiopian traditional beverages, which is made from diverse ingredients. 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 annually in households and drinking houses in Addis Ababa alone. Some of them consider as local beer. It is traditionally drunk on major religious festivals, saint's days and weddings.

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How to cite this article:

Chala Dandessa. 2019. Review on Ethiopian Traditional Fermented Foods, its Microbial Ecology and Nutritional Value. *Int.J.Curr.Res.Aca.Rev.* 7(5), 13-27. **doi:** https://doi.org/10.20546/ijcrar.2019.705.004