Status and Challenges in the Safety and Quality of Dairy Products in Ethiopia: A Review

Alganesh Tola Gemechu
Holeta Agricultural Research Center of Ethiopian Institute of Agricultural Research P. O. Box 2003, Addis Ababa, Ethiopia

Abstract
In this paper, the status and challenges in the safety and quality of dairy products in Ethiopia were assessed with the objective of reviewing the existing scenario, challenges and revealing the gaps in the safety and quality of dairy products in the country. The review revealed that about 98 % of dairy products comes from the traditional informal sector. The major dairy products traditionally produced in Ethiopia are raw whole milk, spontaneously fermented milk ('Ergo' or 'Ittitu'), butter milk ('arera'), cottage type cheese ('ayib'), local butter ('dhadha'), tradtional ghee ('nitir kibe' or 'dhadhaa baksa') and whey. The results of different reports on the safety of dairy products in terms of their microbiological quality parameters such as total aerobic mesophilic bacteria and total counts were substandard. Similarly, the quality parameters in terms of physicochemical characteristics such as freezing points of raw whole milk, specific gravity and several other parameters were below standard. In this review, adulteration of milk is also proved to be an increasing trend. Ingeneral, the dairy products in Ethiopia do not fulfill the minimum standard requirements set by Ethiopian standard and other standards. Furthermore, the information on safety and quality of dairy products in Ethiopia is not comprehensive. Further research and policy guidelines on authentication of dairy products is vital. Future research has to focus on data generation on spoilage and pathogenic microorganisms, drug and pesticide residue levels, aflatoxin and adulteration practices in dairy products. There is a need to devise means of promotion of modern dairy industry that is responsive to market demand and public health concerns through enforcing quality assurance programs and fulfillment of minimum standard requirements for delivery of authentic dairy products.
Keywords: Safety, quality, challenges, dairy products

Introduction

Food safety and quality are a growing concern all over the world particularly from human health point of view. In this respect, many countries are implementing quality control programs for all food items including animal products (Buzby and Roberts, 1996; Elziney and Alturki, 2007). Safety of food is a basic requirement of food quality that implies absence or acceptable and safe levels of contaminants, adulterants, naturally occurring toxins or any other substance that may make food injurious to health on an acute or chronic basis. Food quality can be considered as a complex characteristic of food that determines its value or acceptability to consumers (Elziney and Alturki, 2007).

Milk that satisfies good hygienic conditions is necessary to produce milk products of good quality and adequate shelf life in order to provide safe food for the consumer (O'Connor, 1994). Indigenous dairy products are traditionally produced and consumed in many African countries including Ethiopia (Ashenafi, 1996; Almaz et al, 1999). The different milk constituents significantly contribute to the requirements of human nutrition. Moreover, milk and dairy products are important sources of protein, calcium, phosphorus, iodine, riboflavin and vitamins A and B12 (Jéssica *et al*., 2014). The quality of dairy products is critical to the dairy industry and the consumers. However, the milk production chain in some developing regions still faces many challenges related to the dairy products quality and safety to meet legislations and the needs of consumers (Jéssica *et al*., 2014).

Consumers generally demand for products of consistent quality, standards, hygiene, proper presentation and ease of use. Different organizations have been working in different countries to establish quality and safety standards to ensure the health of consumers. Health hazards to the consumer are often grouped into microbiological, physical and chemical hazards (Walstra et al., 2006).

The key Issues identified to be considered as the most basic chemical, microbiological and physical standards in milk products concerns the levels of appearance, flavor, taste, temperature, solids not fat, freezing point depression, antibiotics, acidity, sediment, resazurin, total bacteria and other important microbial counts (Mansel, 2010). The above mentioned factors can more be elaborated in terms of a range of factors that can lead to food being unsafe due to poor handling and storage conditions, naturally occurring toxins in food itself, contaminated water, pesticides and drug residues and lack of adequate temperature control.

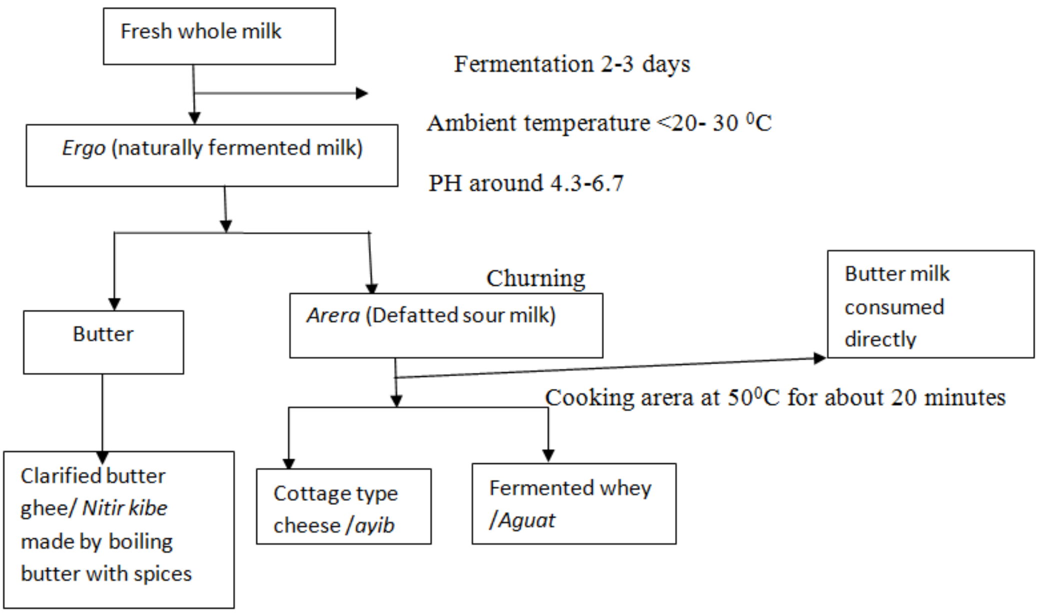
In Ethiopia, more than 98 % of milk and milk products are produced in rural areas and milk marketing is through the informal channel and only about 2 % of milk products are formally marketed (Tsehay, 1998). In the country, the indigenous dairy products are produced using traditional materials and methods. The materials used for milk handling and processing are local materials made of bottle gourds, clay pots. Recently plastic containers are also used. These materials are reported to be reservoirs for many microorganisms and difficult to clean (O'Connor 1994, Zelalem *et al*, 2007; Alganesh and Fekadu, 2012; Abebe *et al*., 2013).

In Ethiopia, consumption of raw milk and milk products is common on view of public health hazards; this may lead to the transmission of various diseases (Zelalem *et al*., 2011; Bilatu *et al*., 2013). Earlier reports by Zelalem (1999); Ashenafi (2006); Asaminew and Eyasu (2011); Alganesh and Fekadu, 2012 and Amistu *et al*. (2015) indicated that hygienic practices during production, processing and handling of milk and milk products in different parts of Ethiopia were substandard and the quality and safety of milk products is questionable. Such safety problems in extreme cases can have negative impact on the food security status of the country. Apart from the quality and safety concerns, poor handling practices in the country causes postharvest losses (FAO, 2011; Bilatu *et al*., 2013).

Previous report in the country estimated a post harvest losses of dairy products of up to 40% from milking to consumption (Felleke, 2003). Although, the Ethiopian standard authority has set standards for indigenous and imported dairy products, the standards were not enforced to control and assure the safety and quality of dairy products. Hence, there are no strict regulations and quality assurance techniques on production, processing, packaging, transportation and marketing of dairy products in the country. Furthermore, research undertakings during the last half century had focused on increasing milk production without giving much emphasis to safety and quality of dairy products. Consequently, few fragmented research works were undertaken on this aspect. Therefore, this paper is intended to review the existing scenario, challenges and reveal the gaps in the safety and quality of dairy products in Ethiopia.

Traditional milk handling and processing practices in Ethiopia

The indigenous dairy products produced and consumed in Ethiopia are whole milk, butter milk (arera), traditionally fermented milk (ergo), cottage type cheese (ayib), traditional semi-hard cheese (metata ayib), whey, local butter and ghee. Whey is considered as a byproduct (O'Connor, 1994; Almaz *et al*., 2001; Zelalem 2001; Yitaye *et al*., 2009; Alganesh and Fekadu, 2012; Abebe *et al*, 2013). Cows are the main source of milk in Ethiopia. It is cows' milk that is the major focus of milk processing in Ethiopia. Dairy processing in the country is generally based on 'ergo' (spontaneously fermented milk), with natural starter culture. In the rural areas, raw milk is kept at ambient temperature or kept in a warm place to ferment prior to processing (Mogessie, 2002). Dairy processing in the country is basically limited to smallholder level and hygienic qualities of products are generally poor (Zelalem and Faye, 2006). The same author revealed about 52 % of smallholder producers and 58% of large-scale producers use common towel to clean the udder of cows prior to milking. While the smallholders producers do not clean cow's udder at all. The smallholders neither use clean water to clean the udder nor other milk utensils (Zelalem and Faye, 2006). In general, the majority of smallholders do not treat milk before consumption. Organoleptic properties (such as color and odor) of dairy products are commonly used quality tests (Sintayehu *et al*., 2008). The typical traditional milk processing technique in Ethiopia is shown below in Figure (1).



Safety and quality of dairy products and significance of bacterial contamination

Due to its complex biochemical composition and high water activity, milk serve as an excellent culture medium for the growth and multiplication of many kinds of microorganisms (Ashenafi and Beyene (1994). Presence and multiplication of saprophytic bacteria in raw milk might change the milk composition and influence the quality of the products (Godefay and Molla, 2000). Moreover, the flavor of the raw milk may be adversely affected and heat stable bacterial enzymes may continue to act in the product. Particularly during long storage, it unfavorably affects stability and/or flavor of final products (Heeschen, 1994).

The bacterial contamination in milk emanates from a number of sources including mastitis, external udder surfaces and the milking plant (Walstra *et al*., 2006). Inadequate cooling of the milk, improper udder preparation, unclean milking equipment and water used for cleaning purposes are considered as the main source of milk contamination (Graaf *et al*., 1997). In the traditional milk production and processing system in Ethiopia, the sources of milk contamination are the udder and body of the milking animal, the milking environment (the barn, dust and dirt from feed sources, the air).

The traditional vessels used for milking, the water used for cleaning milk vessels and the person who milks the animal and handles the milk are also among the potential sources of contamination (Ashenafi and Beyene, 1994; Zelalem and Inger 2001; Alganesh and Fekadu, 2012). Moreover, the conditions necessary for bacterial multiplication are moisture, suitable temperature, air and nutrient. Milk which supplies all these essentials to bacterial existence is one of the most favorable media for the growth of microorganisms (Walstra *et al*., 2006).

Microbial criteria requires that specific microorganisms or toxins produced by a microorganism must not be present at all, are allowed in a limited number per gram of samples, or be present at less than a specified number or amount in a given quantity of a food ingredient (Michael and Joseph, 2004). Different microbiological tests are used to indicate the hygienic condition during the manufacturing of a given product. A commonly used procedure to measure the sanitary quality of milk is to estimate its bacterial content. The number of bacteria in aseptically drawn milk varies from animal to animal and even from different teats of the same animal. On average, aseptically drawn milk from healthy udders contains between 500 and 1000 bacteria/ ml of milk sample. High initial counts (more than 10^5 bacteria/ ml) are evidence of poor hygienic production (O'Connor, 1994). Coliform count provides an indication of unsanitary production practices and/or mastitis infection. A coliform count less than 100 cfu/ml is considered acceptable for milk intended to be pasteurized before consumption. Counts of 10 cfu/ml or less are achievable and desirable if raw milk is consumed directly (Ruegg, 2003).

Somatic cell count (SCC) is another indirect indicator of the microbial quality of milk. The number of somatic cells increases in response to pus-producing bacteria like *Staphylococcus aureus*, a cause of mastitis (Kleinschmit and Gompert, 2007). There shouldn’t be any drug residue in milk intended for direct consumption or processing. Different countries have safety limits of somatic cell count and drug residue for raw milk. In many countries, a standard for Grade ‘A’ raw milk is standard plat count (SPC) of <10 cfu/ml for milk intended for heat treatment before consumption or further processing.

Safety and Quality of Raw Cow milk in Ethiopia

According to Shunda *et al.* (2013) the mean aerobic mesophilic bacterial count (AMBC) of 180 milk samples that were collected from dairy farms, vending shops, homes and cafeteria in Mekelle, Northern Ethiopia was 7.35±0.180, 7.35±0.180 and 7.42±0.272 log cfu/ml, respectively. A report on samples collected from in and around Boditti town, Southern Ethiopia had mean value of AMBC, coliform counts of 6.36±0.24 log cfu/ml (Asrat *et al*., 2012). Another report from Ezha district of Southern Ethiopia revealed AMBC of 9.82 log cfu/ml (Abebe *et al*., 2012).

A study conducted on the udder of cows, producer storage containers and distribution containers in Hawassa, Southern Ethiopia revealed overall mean value of AMBC to be 4.57, 7.28 and 10.28 log cfu /ml, respectively (Haile *et al*., 2012). Another study in mid rift valley by Fikirneh et al. (2012) revealed average AMBC and coliform counts of milk as 4.35 ± 0.06 and 7.08 ± 0.07 cfu/ml, respectively. Another study in Jimma, Western Ethiopia showed mean count of 7.5±0.8 and 6.06±0.6 log cfu/ ml of AMBC and lactic acid bacteria (LAB), respectively (Alebel *et al*., 2013). Milk samples collected in Jimma town from 47dairy herds had mean value of AMBC of 9.62×10^5cfu/ml (Tadele, 2013). The overall mean for 100 raw cow milk samples collected from individual producers and dairy farms in Jimma revealed AMBC, LAB and Staphylococci counts of 8.7±1.34log cfu/ml, 8.27±0.98 log cfu/ml, 4.24±0.76 and 4.94±0.31log cfu/ml, 5.27±0.31 and 5.18±0.64 log cfu/ml, respectively (Tadesse and Bacha, 2014).

A study conducted on dairy farms and milk vendors in Dire Dawa town, had average AMBC of 5.84±0.629 and 9.137±0.885 log cfu/ml, respectively (Teklemichael *et al.*, 2013). A mean value of AMBC from milk samples from producers and dairy cooperatives in Bahir Dar Zuria and Mecha district, North-western Ethiopia was 7.61±0.12 and 7.56±0.13 log cfu/ml, respectively. The overall mean of AMBC of milk samples collected from Shambu, Fincha and Kombolcha, East Wollega was 9.73±0.49, 9.62±0.31 and 9.78±0.38 log cfu/ml, respectively (Demissu, 2014). A previous report by Alganesh *et al*. (2007) on AMBC of raw whole cow milk samples produced in Bila Sayo and Guto Wayu districts of Eastern Wollega, Ethiopia was $7.4\text{x}10^7$ and

$2x10^7$ cfu/ml, respectively. The same authors revealed total bacterial count of $2.9x10^4$±0.02 cfu/ml for milk samples collected from the two districts of East Wollega.

The mean AMBC and LAB counts of milk samples collected from producers and dairy product shops revealed 8.38 and 7.68 log cfu ml/ and 6.97 and 6.81 log cfu/ ml, respectively (Zelalem and Bernard, 2006). According to Dehinenet *et al.* (2013) the mean AMBC counts of milk samples collected from Amhara and Oromia National Regional States of Ethiopia was $1.1x10^8$cfu/ml. Average AMBC of 9.10 log cfu/ml were reported from milk samples collected from dairy potential areas in the Ethiopian highlands (Zelalem, 2012). A study conducted in Debre Brhan, Selale and Holeta showed average total AMBC of whole milk samples of 7.6 log cfu/ml (Samson *et al*., 2012). Another study conducted by Alganesh (2016) in Ejere, Walmera, Selale and Debre Berhan revealed 8.2 log cfu/ml, 8.58 log cfu/ml and 11.36 log cfu/ml of aerobic mesophilic bacteria, total coliforms and Enterobacteriaceae, respectively. Raw milk samples collected from cow udder and storage containers from Abaya District of Borana pastoral area on AMBC and *Staphylococci* count showed minimum and maximum values of 6 and 8.47 log cfu /ml and 6.08 and 8.10 log cfu/ml, respectively (Tollossa, 2012). Generally, all milk samples analyzed were substandard compared against the Ethiopian and European standards (Table 1).

Table 1. Ethiopian standard requirements for unprocessed whole /raw cow milk and pasteurized liquid milk based on bacteriological limits

Aerobic mesophilic bacteria	
Quality	Counts (per ml)
Very good	0 – 200,000
Good	200,000 – 1,000,000
Bad	1,000,000 – 2,000,000
Very bad	2,000,000 and over
Coliforms	
Quality	Counts (per ml)
Very good	0 – 1,000
Good	1,000 – 50,000
Bad	50,000 – 500,000
Very bad	500,000 and over
Pasteurized liquid milk	
Microorganisms/groups of microorganisms	Requirement
Total plate count	
Very good quality	<$5x10^4$per ml
Good quality	$5x10^4$ – 10^5 per ml
Fecal coliforms	Nil per ml
Non fecal coliforms	<10 per ml

Source: Reference number: ES3461:2009

A study conducted by Dawit et al. (2015) on aflatoxin contamination of milk and dairy feeds in the greater Addis Ababa milk shed revealed high contamination of concentrate feed sources and milk with aflatoxins (Table 2). All milk and feed samples had detectable levels of aflatoxins. The majority (93%) of milk samples exceeded the limit of 0.05 mg/L set by the EU. Moreover, there is scanty information on aflatoxins in milk products of the country.

Table 2. Summary of aflatoxin M1 contamination of milk in the Addis Ababa milk shed

AFM1	**(mg/L) Dairy farm (N=100)**	**Milk collector (N=10)**
Mean± SD	0.39±0.89	0.69±0.76
Median	0.092	0.29
Minimum	0.028	0.093
Maximum	4.98	2.24

Source: Dawit *et al*., 2015

Indirect tests of microbial quality of raw milk: Alcohol and clot on boiling tests

The alcohol test, together with the acidity test, is used on fresh milk to indicate whether it coagulates on processing. Milk that contains more than 0.21 % acid or calcium and magnesium compounds in greater than normal amounts coagulates when alcohol is added (O'Connor, 1994). Acidity decreases the heat stability of milk. The clot-on-boiling test is used to determine whether milk is suitable for processing, as it indicates whether milk is likely to coagulate during processing (usually pasteurization). If the milk fails the test it is rejected. The test measures the same characteristics as the alcohol test but is somewhat more lenient (0.22 to 0.24% acidity, as opposed to 0.21% for the alcohol test). It has the advantage that no chemicals are needed. However, its disadvantage is that at high altitude milk (like all liquids) boils at a lower temperature and therefore the test becomes more lenient (O'Connor, 1994).

The overall mean for clot on boiling test showed only 21% of the milk samples tested in Bila Sayo and Guto Wayu of East Wollega were likely to clot on boiling. The alcohol test showed 58 % of the milk samples were likely to clot (Table 3). The difference in percentage of the two tests indicates that clot on boiling has certain drawbacks so that it should be followed by alcohol test. The result indicated that there is higher percent of lactic acid in the milk samples. This was probably due to initial contamination of the milk samples either from containers or the general milking environment (Alganesh and Fekadu, 2012).

Table 3. Predicted probabilities (± SE) for clot on boiling and alcohol tests of milk samples collected from Bila Sayo and Guto Wayu districts of East Wollega

Location	**Clot on boiling test Predicted probabilities (± SE)**	**Clot on boiling test Predicted probabilities (± SE)**	**Ethiopian Standard**
Overall mean	0.21±0.06 (21%)	0.58±0.07	Alcohol test should be negative and milk should not coagulate on clot on boiling
Bila Sayo	0.15±0.07	0.63±0.09	
Guto Wayu	0.30±0.09	0.54±0.10	

Source: ES, 2009; Alganesh and Fekadu, 2012

In another study conducted in Adea Berga and Ejere districts 32.2% of milk samples were positive for alcohol tests and only 18.8 % were positive for clot-on-boiling tests. Milk samples collected from dairy cooperative unions, processors and consumers had high values of clot on boiling and alcohol tests in Ejerie and Adea Berg districts compared to milk samples collected from individual producers (Table 4).

Table 4. Alcohol and clot on boiling tests on milk in Ejere and Adea Berga areas of central Ethiopia

Milk sources	N	Positive results in percents (%)	
		Alcohol	Clot-on-boiling test
Ejerie District			
At farm gate	20	10	-
At coop gate	10	20	10
Bulked milk at coop	6	33.3	16.7
		Ada Berga district	
At farm gate	20	15	-
At coop gate	10	30	30
Bulked milk at coop	6	50	33.7
Dairy coop union	6	66.7	50
Processors	6	83.3	50
Consumers	6	83.3	66.7
Overall mean	90	32.2	18.8

N= number of milk samples Coop= dairy cooperatives, Source Saba, 2016

Asamnew and Eyasu (2011) also reported 51% of smallholders and dairy cooperatives milk sample were clotted on alcohol tests and only 23% of milk samples were clotted on clot boiling test in Bahirdar area and Mecha districts in Amhara region.

Quality of raw whole milk

About 87% of milk is water, in which the other constituents are distributed in various forms. The chemical composition, particularly milk fat content is used as quality parameter (Michael and Joseph, 2004). The nutritional as well as the economic value of milk is directly associated with its total solids content. The higher the solids content the better is its nutritional value and more of a milk product can be made (Pandy and Voskull, 2011). Protein content is one of the main quality determining criteria applied to milk payment for producers in many countries. Others price their milk according to fat and solids-non-fat composition (FAO, 2004).

Milk acidity is another important indicator of milk quality. Acidity measurements are also used to monitor processes such as making cheese and yoghurt. Fresh cow milk has a pH of 6.5 - 6.7. Values higher than pH 6.7 indicate mastitic milk and values below pH 6.5 indicates the presence of colostrum or bacterial deterioration. Because milk is a buffer solution, considerable acid development may occur before the pH changes. A P^H lower than 6.5 indicates that considerable acid development has taken place. This is normally due to bacterial activity (O'Connor, 1994). The titratable acidity of milk is expressed in terms of percentage lactic acid, the principal acid produced by fermentation after milk is drawn from the udder. Fresh milk contains only traces of lactic acid. However, due to the buffering capacity of the proteins and milk salts fresh milk, in which no lactic acid has been produced, normally milk exhibits an initial acidity of 0.14 to 0.16 % when titrated using sodium hydroxide to a phenolphthalein end-point (O'Connor, 1994).

A study report on chemical composition of raw milk samples from mid rift valley by Fikirneh *et al.* (2012) indicated % fat, protein and solids non fat to be 5.48 ± 0.19, 3.46 ± 0.04 and 9.10 ± 0.09, respectively. A study conducted on determinants of raw milk quality under a smallholder production system in selected areas of Amhara and Oromia National Regional States revealed 5.2 %, 8.44, 3.31, 3.12, fat, SNF (solids not fat), density and protein, respectively (Dehinenet *et al*., 2013). A report on raw cow milk in Shashamane on total solids, fat, SNF, protein, ash and lactose revealed 12.87±0.01, 4.28±0.01%, 8.59±0.07%, 3.43±0.00%, 0.74±0.01%, 4.43±0.06%, respectively (Teshome *et al*., 2015). Another study conducted in Adea Berga and Ejerie Districts of West Shewa Zone revealed overall average contents of fat, protein and total solid contents of raw whole milk of 3.5 %, 3.09 % and 12.19 %, respectively (Saba, 2016). A report by Alganesh (2016) in four Ejere, Walmera, Selale and DebreBerhan of central highlands of Ethiopia showed over all mean fat, protein, total solids, ash, lactose and SNF as 3.76 %, 3.10 %, 12.24 %, 0.61 %, 5.08 % and 8.56 %, respectively. The same author showed mean titratable acidity of milk samples in four study locations to be 0.27 (% lactic acid). Previous report by Alganesh et al., (2007) in two districts of East wollega showed % total protein, total solids, solids not fat, fat, ash, casein and lactose as 3.31±0.01, 14.31±0.03, 8.22±0.01, 6.05± 0.02, 0.70±0.01, 2.63±0.01and 4.51±0.01, respectively. Similar study conducted by Tekle michael (2012) revealed a protein content of 3.42 % for milk samples collected from dairy farms in Dire Dawa. The chemical components such as protein, total solids and ash in most of the reports were below the standard set by the Ethiopian Standard Authority and the European Standards according to (Table 5).

Table 5. Requirements set by Ethiopian standards for physico chemical components of unprocessed whole raw cow milk and pasteurized liquid milk

Characteristics	Requirements	Method of test
Fat content, whole milk, min, % by mass	3.5	ES ISO 1211, ES ISO 2442
Fat content, Fat reduced milk, % by mass	1.5-3.5	ES ISO 1211, ES ISO 2442
Fat content, low fat milk, % by mass	0.5-1.5	ES ISO 1211, ES ISO 2442
Protein, min, % by mass	3.20	ES ISO 5542, ES ISO 8968-5, ES ISO 8968-1
Total solids, min, % by mass	12.80	ES ISO 6731
Phosphatase test	Negative	ES ISO 3356
Antibiotics	None	ES3473
Pesticide residues	See 13557	ES ISO 3890-1, ES ISO 3890-2
Freezing point	0.525-0.550	ES ISO 5764
Milk fat content min, % by mass	3.50	ES ISO 1211, ES ISO 2442, ES ISO 17189
Protein, min% by mass	3.20	ES ISO 5542, ES ISO 8968-5, ES ISO 8968-1
Total solids, min, % by mass	12.80	ES ISO 6731
Antibiotics	Nil	ES3473
Freezing point, ^{o}C	0.525--0.550	ES ISO 5764
Pesticide residue	See ES 3472	ES ISO 3890-1, ES ISO 3890-2
Aflatoxin M1, max µg/L	0.05	ES ISO 14501, ES ISO 14674
Alcohol test	Negative	ES 3471
Clot on boiling test (COB)	not coagulate	ES 3458
Essential composition of pasteurized liquid milk		
Fat content, whole milk, min, % by mass	3.5	ES ISO 1211, ES ISO 2442
Fat content, Fat reduced milk, % by mass	1.5-3.5	ES ISO 1211, ES ISO 2442
Fat content, low fat milk, % by mass	0.5-1.5	ES ISO 1211, ES ISO 2442
Protein, min, % by mass	3.20	ES ISO 5542, ES ISO 8968-5, ES ISO 8968-1
Total solids, min, % by mass	12.80	ES ISO 6731
Phosphatase test	Negative	ES ISO 3356
Antibiotics	None	ES3473
Pesticide residues	See 13557	ES ISO 3890-1, ES ISO 3890-2
Salmonella	Nil	ES ISO 6785
Freezing point	-0.525to -0.550	ES ISO 5764

Source: Reference number: ES3461:2009

Physical properties of milk

A study conducted on determinants of raw milk quality under a smallholder production system in selected areas of Amhara and Oromia National Regional States, Ethiopia revealed 1.19 % and 0.559 ^{0}C adulteration and freezing point, respectively (Dehinenet et al., 2013). A report on raw cow milk in Shashamane on temperature, PH value, specific gravity and titratable acidity revealed values of 22.83±1.22 ^{0}C, 6.32±0.07, 1.030±0.00, 0.194±0.006 (% lactic acid), respectively (Teshome *et al*., 2015). Another report by Alganesh *et al (*2015) on raw and pasteurized milk samples from Addis Ababa, Oromia, Amhara and Southern regions of Ethiopia showed adulteration ranges of 0.56±0.05 to 27.80±0.42 % with mean value of 2.45 %. In this study high levels of adulteration were detected in branded pasteurized milk samples. Alganesh *et al (*2015) revealed overall average freezing point for the milk samples as 0.0260C. Adulteration of milk at different points to increase its quantity can increase freezing point. Under feeding of milking cows can also increase freezing point (Douglas, 1995). According to the Ethiopian Standards Authority raw whole cow milk has to have freezing point of - 0.525 to -0.550 ^{0}C (ES, 2008). The US standard for freezing point of milk is -0.512 to -0.550 ^{0}C (Douglas, 1995). The overall average milk temperature reported by Alganesh *et al*. (2015) was 20.67^{o}C. Under normal condition, milk should be cooled to 4^{0}C immediately or it should be transported to a market point within 3 hours after milking. Cooling milk slows down the growth of spoilage bacteria and prolongs the shelf life of milk (Lore *et al*, 2006). Inadequate cooling increases bacterial counts by allowing a better environment for bacterial growth during storage (Douglas, 1995).

According to Alganesh *et al.* (2015) the overall average specific gravity of milk samples collected from different regional states showed 1.021g/ml (Figure 3). Other on-farm studies by Zelalem and Ledin (2001); Alganesh *et al.* (2007) and Teshome *et al*. (2015) revealed specific gravities of 1.030, 1.030 and 1.030 from samples collected from smallholder producers in East Wollega, central highlands of Ethiopia and dairy cooperatives, hotels, kiosks and small shops of Shashamane town, respectively. Based on the fact that milk has density, the specific gravity of normal milk ranges from 1.026–1.032 g/ml at 20^{0}c compared to water (1.000 g/ml). When milk is adulterated with water or other solids, the density either decreases if water is added or increases if solids are added. If milk fat or cream is added to milk, the density/specific gravity decreases (O'Connor, 1994; Lore, *et al*. 2006). The normal range for milk specific gravity standard set by the European Union ranges from 1.027 -1.035 g / ml with a mean value of 1.032 g / ml (Tamime, 2009). Some of specific gravity results discussed above was below the standard. This indicates the increasing trend of adulteration practices probably by water and other adulterants.

Safety and quality of 'Ergo' (spontaneousely fermented milk)

'Ergo' is a traditional fermented milk product, which is made by natural fermentation of milk under ambient temperature, with no defined starter cultures used to initiate the fermentation processes (Assefa et al., 2008). As a result, the microbial load of fermented milk samples, including 'ergo*'*, could vary from sample to sample based on the microbial load and types of microbes in the original raw milk (Abdulkadir et al., 2011). It is semi-solid, smooth and uniform in appearance and usually has color of milk with pleasant odor and taste when prepared carefully. It constitutes primary sour milk from which other products may be processed. Depending on the storage temperature, it can be stored for 15-20 days (Almaz et al., 2001). It is popular and is consumed in all parts of Ethiopia by all age categories of people (Yonad, 2009).

It has been found that lactic acid bacteria (LAB) dominated all other microorganisms, followed by yeasts and moulds in 'ergo'. Almaz *et al*. (2001) reported that 'ergo' fermentation is carried out by LAB belonging to the genera *Lactobacillus, Lactococcus, Leuconostoc, Entrococcus* and *Streptococcus*. The same authors reported that *Micrococcus* sp., coliforms and spore formers were also present in fairly high numbers during the first 12-14 hours of fermentation. Their population decreased substantially thereafter, which implies an antimicrobial activity besides low pH in the fermented milk (Savadogoo *et al*., 2004). The report of Esayas *et al*. (2008) indicated different LAB isolates from 'ergo' (Table 6) which has antimicrobial activities against different pathogenic microbes including Shigella flexinery, *Salmonella typhi*, *Escherichia coli* and *Staphylococcus aures*.

Table 6. Microorganisms associated with' ergo' Ethiopian fermented dairy product

Ethiopian Fermented Dairy Products	pH	Titrable acidity	Associated Microorganisms
'Ergo' or 'Ittitu*'* (naturally fermented milk)	4.3	0.88	*Lactococcus garvieae* *Lactococcus lactic* subsp. *lactic* *Lactococcus, Streptococcus, Leuconostoc* *Lactobacillus* Food-borne pathogens *Salmonella* spp., *Bacillus cereus* *Staphylococcus aureus*, *Listeria monocytogene* *Lactobacillus casei Lactobacillus plantarum*

Source: Esayas *et al*., 2008

According to Ashenafi (2002), in most households of Ethiopia, no attempt was made to control the fermentation process of milk and milk products manufactured under traditional systems. These products have poor qualities and do not meet the acceptable quality requirements set by various regulatory agencies (Ashenafi, 2002). Zelalem (2010) revealed that mean yeast and mould counts exceeded 8 log cfu/ml for 'ergo' sampled from different part of the country. A former report also showed yeast and mould counts of 4.6 log cfu/ml for fermented milk sampled from Southern Ethiopia (Fekadu, 1994). The presence of different species of yeast in milk and its products may result in the spoilage of the product or conversely could contribute to the enhancement of flavor of fermented milk, since different yeast species are able to assimilate different milk substrates (Ashenafi, 2002). Zelalem et al. (2007) isolated *Klebsiella pneumoniae*, *Klebsiella oxytoca*, *Enterobacter cloacae*, *Citrobacter freundii* and *Enterobacter sakazakii* from ‘ergo’ samples collected from smallholder producers in the central Ethiopia.

The average total bacterial count during ‘ergo‘ fermentation in raw milk collected from eight dairy farms in Awassa was greater than 9 log cfu/ml (Ashenafi, 1995). Similarly, total bacterial count of ergo was 7.71 log cfu/ml in samples collected from Sheno (Zelalem, 2010). Fekadu (1994) also reported 8.6 log cfu/ml total bacterial counts for 75% of fermented milk samples collected from three villages in Southern Ethiopia. Coliform count averaging 6.57 log cfu/ml was reported for ‘ergo’ samples from central highlands (Zelalem and Faye, 2006). Enterobacteriaceae and coliform counts of 4.95 log cfu/ml were reported from Sheno (Zelalem, 2010). The existence of coliform bacteria in milk and milk products is suggestive of fecal contamination and unsanitary practices during production, processing or storage (Fekadu, 1994). However, the traditional milk processing techniques involve smoking of vessels using embers of *Olea fricana* (Fekadu, 1994). *Deinboll kilimandshorica* and 'Gaarrii' are also commonly used for smoking milk vessels in East Wollega (Alganesh and Fekadu, 2012). The use of herb *of Ocimum hardiense* for cleaning milk vessels and leaves and stems of *Ocimum urticifolium and Ocimum hardiense* to rub milk containers for flavor impartation is common in different parts of Ethiopia (Lemma Fita 2004; Alganesh and Fekadu, 2012; Fikrneh *et al*., 2012). These practices were reported to be beneficial to keep better quality of ‘ergo’ through their inhibitory effects on spoilage and pathogenic organisms. For instance, the inhibitory effect of smoking on *Listeria monocytogenes* was reported by (Ashenafi and Fekadu, 1994). The effect of lower pH of ‘ergo’ in controlling the proliferation of undesirable microorganisms is more effective after 24 h of incubation (Ashenafi, 2006). The same author recommended that milk should be boiled before hand and a small amount of three days old ‘ergo’ that is free from pathogens but contains enough lactic acid bacteria should be inoculated in ‘ergo’ to initiate fermentation.

Safety and quality of kibe’ (traditional Ethiopian butter)

Traditional Ethiopian butter ‘kibe’ is always made from ‘ergo’ and not from cream (O’Connor, 1994). Traditional butter is processed and sold by women in every community (Yonad, 2009). ‘Kibe’ has an attractive appearance with a white to light yellowish color. ‘Kibe’ is semi-solid at room temperature. It has pleasant taste and odor when fresh, but with increased storage changes occur in odor and taste, unless refrigerated or further processed into ‘nitir kibe’ by boiling with spices. ‘Kibe’ is the most shelf stable of all traditionally processed fermented milk products next to ‘nitir kibe’. ’Kibe’ has important role in the diet, both in rural and urban areas, and is utilized by children of weaning age and the elderly. In addition to direct consumption as a side dish, it is used as oil for food preparation. It is also used for hairdressing and as a skin cosmetic by both sexes. It is used for roasting coffee beans that is used for special traditional ceremonies (Mekdes, 2008; Yonad, 2009; Alganesh and Fekadu, 2012).

Spoilage occurs when butter is stored at room temperature for a long time mainly by putrefactive microorganisms. Microorganisms having lipolytic activity are highly responsible for disorders such as rancidity or bad flavor. According to Zelalem (2010) butter samples collected from Selale area average total bacterial counts of 7. 25 cfu/gram of butter. According to previous report by ILCA (1992), the total bacterial count of fresh butter sampled from rural and public butter markets in Addis Ababa ranged from 8.27 to 4.7 log cfu/g. A study conducted by Mekedes (2008) in southern Ethiopia on samples collected from open markets in Delbo and Kucha areas in southern Ethiopia revealed mean total bacterial counts of 8.19±0.12 log cfu/g. The mean AMBC in fresh butter samples collected from Ambo and Dire Inchini districts of west shewa revealed 8.71log cfu/g (Debela, 2016).

Total coliforms as hygiene indicator can be used as important criteria for determination of microbiological quality of butter (Zelalem, 2010). The same author reported coliform counts ranging from 1.92 to 4.5 log cfu/gram of butter. Enterobacteriaceae counts of greater than 4 cfu/g of butter samples were also reported from different parts of the country (Zelalem et al., 2007). The presence of coliform groups in dairy products indicates the probability of fecal contamination of the dairy product. These differences could be attributed to the wide variation in hygienic handling during milking, processing, storage and transport to market. All the results indicated that ‘kibe’ produced in different part of the country were produced and handled under substandard conditions at all stages in the milk chain.

The primary spoilage factors in butter are mostly greenish moulds. But red, black and brown colored moulds are also seen in butter. The majority of moulds growing in butter are composed of species of Thamnidium, Cladosporium and Aspergillus. The presence of mould contamination in butter indicates contamination by water or air after production. The mean yeast and mould count observed in the Ethiopian highlands was 8 cfu/g of butter (Zelalem, 2010). According to Mekdes (2008) yeast and mould counts ranged between 4.3 and 6.86 log cfu/g of butter sampled from Wollayta area. Microbiological information on this product is not fully available in Ethiopia. The results on butter microbial tests done so far do not fulfill the requirements set by Ethiopian standard (Table 7).

Table 7. Ethiopian standards requirements on microbiological limits for butter

Microorganism	Maximum limit	Method of Test
Total plate count	1000000/ml	ES ISO 6610
E. coli	Absent/ml	ES ISO AA866-1, ES ISO AA866-2
Salmonella	Absent/25ml	ES ISO 6785
Molds and Yeasts	10/ml	ES ISO 6611

Source: ES3461:2009

The chemical composition of butter samples studied by Mekdes (2008) in southern Ethiopia revealed mean values of total solids, fat and ash percents of 85.84±1.02, 81.53±1.00 and 0.16±0.004, respectively. The average moisture content of butter collected from open markets of Delbo and Kucha was 18.86±1.02 % /gram of butter samples. Generally, there is scanty information on chemical composition of butter in the country (Mekdes, 2008). The result in the above report does not comply with the Ethiopan standard requirement (Table 8).

Table 8. Ethiopian standards requirements for chemical composition of butter

Characteristics	Requirements	Method of test
Butter fat, min, % by mass (unsalted butter)	82.0	ES ISO 3727,ES ISO 17189
Butter fat, min, % by mass (salted butter)	80.0	ES ISO 3727,ES ISO 17189
Moisture, max, % by mass	16.0	ES ISO 3727,ES ISO 8851-1, ES ISO 8851-2
Milk Solids-Non-Fat, max, % by mass	2.0	ES ISO 3727, ES 8851-1
Salt, NaCl, max, % by mass	2.5	ES ISO 1738, ES ISO 15648

Source: ES3461:2009

Safety and quality of 'arera' (defatted sour milk)

Arrera is a byproduct of 'ergo' obtained after churning and removal of 'kibe'. It has a similar color to 'ergo'. But its appearance is slightly smoother and its consistency is thinner, although thicker than fresh milk and basically contains the casein portion of milk. Its taste and odor are similar to that of 'ergo'. 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 (EHNRI, 1997). 'Arrera' has a shorter shelf life of only 24-48 hours compared to all other fermented milk products.

The product is consumed in all parts of the country where fermented milk is produced. It is served as a beverage either plain or spiced. It is preferred as a side dish or as drink (Yonad, 2009). Surpluses are given to calves, lactating cows and dogs (Almaz et al., 2001). It also serves as additional income for women by its use as raw material for cottage cheese ('ayib') manufacture, which is sold in the local market. Due to its relatively short shelf life and some traditional taboos, 'arrera' is not sold in the market for direct consumption.

The average counts of total bacteria, Enterobacteriaceae and coliforms from 'arera' sampled from Addis Ababa was greater than 9, 4.7, 4.2 and 4.2 cfu/ml, respectively (Zelalem, 2010). 'Arera' sampled from Wolayta area had total bacterial count of about 9 log cfu/ml (Rahel, 2008). The same author reported coliform count of 4.86 log cfu/ml in Walyta area. Species of bacteria such as *K. pneumoniae*, *K. oxytoca*, *E. cloacae*, *E. sakazakii*, *E. coli* and Salmonella were identified in arera samples collected from different locations (Zelalem et al., 2007).

The chemical composition of butter milk determines the nutritional and flavor properties of the product. There is little information known about nutritional and flavor attributes of 'arera' (Nigussie *et al*., 2016). The following result (Table 9) was the only chemical composition analysis attempt done in Ethiopia.

Table 9. Chemical composition of fermented buttermilk from samples collected in Northern Ethiopia

Samples	**Protein g/100 ml**	**Fat g/100 ml**	**Lactose µg/g**	**Galactose µg/g**	**Glucose µg/g**
Mean±SD	3.04 ±0.18	1.17±0.68	36147±5400	364.1 ±251.9	59.9±100.3
Butter milk type					
SCB	2.98^{a} (0.2)	1.37^{a} (0.8)	36274^{a} (6853)	367.2^{a} (168.5)	65.1^{a}(87.6)
SMB	3.07^{a} (0.2)	1.05^{a} (0.59)	36071^{a} (4513)	362.2^{a} (295.0)	56.8^{a}(109.3)

SD-Standard deviation, SCB- sour cream butter milk, SMB- Sour milk butter milk, Letters in superscript indicate significant difference in mean values at P<0.05. Source: Nigussie *et al*., 2016

Safety and quality of Ethiopian cottage type cheese ('Ayib')

'Ayib' is a soft curd type cheese typical of many regions in Ethiopia. 'Ayib' is made from the defatted sour milk resulting from churning of sour whole milk and heating the defatted sour milk to coagulate the curd (O'Connor, 1994; Binyam, 2008). The product is white, acidic and it is mainly consumed locally. 'Ayib' contributes to the overall nutrition of the people and forms part of the staple diet (O'Connor, 1994). According to Mogessie (1994) different species of microorganisms were isolated from cottage type cheese (Table 10).

Table 10. Microorganisms associated with' ayib' Ethiopian fermented dairy product

Ethiopian Fermented Dairy Products	Associated Microorganisms
'Ayib'(Ethiopian cottage type cheese)	*Microbacterium, Brevibacterium* spp
	Enterobacteriaceae Pseudomonas spp
	Lactobacillus fermenti Lactobacillus plantarumd
	Grow when added to raw cheese milk
	Salmonella typhimurium, Salmonella enteritidis Salmonella infantis

Source: Mogessie, 1994

The occurrences of most food toxins caused by *Staphylococcus. aureus* were the result of poor hygienic practices in the household. *Klebsiella, E. coli*, *Enterobacter* and *Klyuvera* species were also reported to be found in Ethiopian cottage cheese (Seifu *et al*., 2013). Cottage cheese samples collected from an open market in Awassa had high counts of AMBC, yeasts and enterococci (Ashenafi, 2006). Ashenafi (2006) also reported AMBC counts of over 8 log cfu/g of cheese samples. Comparable counts were also reported by (Binyam, 2008). The sources of contamination could be from handlers, milk vessels used for packaging and possibly herbs used for flavor impartation (Ashenafi, 2006). A study conducted by Eyassu (2013) revealed total viable bacterial count ranging from 5.4 to 7.8 log cfu/g for 'metata Ayib' (Ethiopian semi hard cheese) in West Gojjam. Binyam (2008) reported yeast and mould counts in 'ayib' sampled from Shashemane with average counts of 6.35 log cfu/g of sample. The safety of cheese with respect to food born diseases is a great concern around the world and in developing countries (Ashenafi, 2006). This is especially true in Ethiopia where cottage cheese typically manufactured in small dairy farms under poor hygienic conditions is commonly consumed (Alehilign, 2004). Ayib contains 76% water, 14% protein, 7% fat and 2% ash (O'Connor, 1994). Most soft, unripened cheeses are microbiologically unstable due to metabolic activity of bacteria, yeast and mould contaminants. Former report by Ashenafi, (1992) revealed moisture content of cottage cheese to be 79%. However, the moisture content of the 'metata ayib' samples was relatively lower (Table 11). Metata Ayib is an intermediate moisture food. The lower moisture content of 'metata Ayib' may partly contribute to its long shelf life (Eyassu, 2013).

Table 11. Chemical composition of 'metata Ayib'/ a traditional Ethiopian fermented cottage cheese

Constituents	Mean ±SD
Moisture(g100/g)	42.3 ± 5.1
Fat(g100/g)	28.7 ± 8.4
Crude protein(g100/g)	43.0 ± 6.9
Ash(g100/g)	3.2 ± 0.65
Titratable acidity (% lactic acid)	0.43 ± 0.07
pH	4.00 ± 0.1

SD= standard deviation, source: Eyassu, 2013

Conclusion and recommendation

More than 98 % of dairy products in the country come from the traditional sector where dairy production and marketing is informal. The common indigenous dairy products produced in the country include whole milk, naturally fermented sour milk ('ergo'), fermented butter ('kibe'), local ghee ('nitir kibe'), cottage type cheese ('ayib'), semi hard cheese ('metata Ayib'), fermented buttermilk ('arrera') and fermented whey ('aguat'). Methods of production, handling and processing are generally traditional. The materials used for milking, storage, processing and marketing are local materials which are porous, not easy to clean and disinfect and harbor microorganisms. Consequently, the dairy products are substandard and do not fulfill the safety and quality standards. Moreover, standard operating procedures are not followed on clean milk production and handling. Besides, safety and quality standards were not enforced. The information on safety and quality of dairy products in Ethiopia is not comprehensive. Further research and policy guidelines on authentication of dairy products on spoilage and pathogenic microorganisms, drug and pesticide residues, aflatoxins and adulteration practices in dairy products is vital. Generally, there is a need to devise means of promotion of modern dairy industry that is responsive to market demand and public health concerns. This would be possible by enforcing quality assurance programs and minimum standard requirements for delivery of authentic dairy products.

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