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Microbial Properties of Ethiopian Marketed Milk and Milk Products and Associated Critical Points of Contamination: An Epidemiological Perspective

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1. Introduction

In Ethiopia, milk production systems can be categorized into urban, peri-urban and rural, based on location (Reda, 2001). Located around Addis Ababa and regional towns, urban and peri-urban systems are market oriented and make use of the high demand in urban areas. The rural system is part of the subsistence farming system and includes pastoralists, agro-pastoralists, and mixed crop-livestock producers mainly in the highlands. As this system is not market oriented, most of the milk produced is retained for home consumption. The surplus is mainly processed using traditional technologies into more shelf stable products such as *Ergo* (Ethiopian naturally fermented milk), butter, ghee and *Ayib* (Ethiopian cottage cheese) that are marketed through the informal channel (Reda, 2001).

In Sub Saharan countries the traditional sector, which is characterized by small herd size dominated by indigenous zebu breeds of low milk production with very little or no specialized inputs, is the dominant type of production system accounting to 70 - 80% of Africa's cattle population (Ibrahim and Olaloku, 2000). In Ethiopia, around 97% of the annual milk production is accounted by the traditional milk production system (Felleke, 2003), which is likewise dominated by indigenous breeds. Most of the milk produced in the country is accordingly processed on-farm using traditional technologies that are generally not well understood. Most of the very few enterprises currently operating in and around the capital entirely depend on the traditional sector for their milk intake, while others depend on it for the majority of their intake. These underscore the importance of understanding the traditional sector in order to make improvement interventions.

Cows contribute to about 95% of the total annual milk produced by cows and camels at national level (CSA, 2010). In 2010, the cattle population was estimated at about 50.9 million (99.19% indigenous, 0.72% hybrid and 0.09% pure exotic breeds). The female cattle population accounted for about 55% of the total. The large livestock population; the favorable climate for improved, high-yielding animal breeds; and the relatively animal disease-free environment make Ethiopia to hold a substantial potential for dairy development. In 2010, a total of 2940 million liters of milk was produced from about 9.6 million cows at national level. During the same year, dairying has created an estimated

588,000 full-time on-farm jobs. However, Ethiopia is a net importer of dairy products with import values significantly exceeding export values. In five reference years, for instance, export values increased from about 73000 USD in 2005 to 123000 USD in 2009, while import values increased from about 5,6 million USD in 2005 to about 10,3 million USD in 2009 (a 4,7 million USD increment).

The importance of milk in the Ethiopian diet differs according to the farming system and the socio-cultural set-ups. Generally, in the lowlands especially where livestock keeping is the main occupation, milk is consumed by all groups of the society. In the highlands, the rural people are sedentary farmers raising both livestock and crops. The main part of their diet consists of cereals and legumes. Milk is used for rearing calves and children, and the surplus is soured for making different fermented milk products. The major ones include: *Ergo*, *Ayib*, butter (three types of butter can be distinguished namely *Lega*, *Mekakelegna* and *Besal*, which refer to fresh, semi-rancid and rancid), *Nitir kibie* (melted butter or ghee), *Arrera* (defatted sour milk, a by-product of butter-making and a raw material for *Ayib*-making) and *Aguat* (whey). The demand for milk and milk products is a function of several factors that include: population growth, seasonality of demand and supply, low per capita consumption and high transaction costs. The per capita milk consumption (about 17kg) for Ethiopia is much lower as compared to that for Africa (about 25kg), that recommended by World Health Organization (WHO) (200 liters), the 62.5 kg recommended by FAO (1990) as a minimum level to be kept for a balanced diet and the world's per capita average of about 100 liters/year (FAO, 2010).

In Ethiopia, milk marketing system is not well developed and for the majority of smallholder producers, access to market is limited. In year 2010, for instance, only less than 7 percent of the annual milk production is estimated to be marketed at national level. In 2009, there were 180 cooperatives involved in milk production and marketing in the entire nation, accounting for only 2% of the total number of agro-based cooperatives. In most of the cases, existing dairy cooperatives are operating in areas that are accessible to transportation and market. This means that a substantial amount of milk does not reach the market and a number of producers keep on producing at a subsistence level.

Post harvest losses of up to 40% of milk and its derivatives have been reported from milking to consumption (Felleke, 2003). Such losses are mainly attributed to mishandling in the dairy value chain from farm to fork. These include: contamination during milking and further handling coupled with long storage time at high tropical ambient temperature before consumption; deliberate adulteration of milk; substandard handling, transportation and distribution systems; inefficient processing technologies; inadequate fresh milk outlet; and spillage losses during milking. According to FAO (cited by ENA, 2004), the value of annual milk and dairy product losses due mainly to mishandling across five African and the Middle East countries (Kenya, Tanzania, Uganda, Ethiopia and Syria) is over 90 million USD. Reducing such losses and improving quality are effective ways of making more and safer milk available that benefits both producers and consumers.

Provision of milk and milk products of good hygienic quality is desirable from consumer health point of view. This is one reason why milk testing and quality control include hygiene as well as microbial qualities in addition to testing for fat content and heat stability (Giangiacomo, 2000). The consumption of raw milk and its derivatives is common in Ethiopia (Yilma, 2003), which is not safe from consumer health point of view as it may lead

to the transmission of various diseases. Prior to the discovery and widespread adoption of pasteurization for instance, raw milk and its products were responsible for serious bacterial infections such as diphtheria, scarlet fever and tuberculosis (Spreer, 1998). The consumption of unpasteurized, incorrectly pasteurized or post pasteurization contaminated milk and its derivatives have been reported to cause illnesses (Duffy, Garvey & Sheridan, 2002; Desenclos *et al.*, 1996; Cody *et al.*, 1999).

Consumers all over the world are increasingly concerned about the safety of their food in general and milk and milk products in particular. Therefore, quality should not be ignored at all stages of the dairy value chain from farm to table. As the bacterial quality of raw milk is important to product shelf-life, flavor and product yield, it is important that dairy enterprises should strive to obtain the highest quality raw material possible from their own farm as well as their suppliers. It is therefore essential to produce best quality raw milk in the dairy barn in order to manufacture milk products of not only acceptable quality but of high standard premium throughout the year.

Putting a functional quality control system in place is an important tool to bring about improvement in the dairy sector. However, in Ethiopia there is no a properly operational formal marketing and grading system that is geared towards relating quality of products to market price. Establishing a formal marketing system that relates quality to market price has a potential to enhance commercialization of the smallholder dairy sector. Such an approach provides an incentive for producers to supply products of good quality from nutritional as well as consumer health perspective.

2. Study approach

This chapter is essentially based on primary data collection using questionnaire, key informants, group discussions, personal observation and review of available literature. Data were generated from ten dairy potential areas in the Ethiopian highlands (Addis Ababa, Asella, Debre Birhan, Debre Zeit, Holetta, Sululta, Selale, Adama, Sheno, Jimma). A semi-structured questionnaire was used to collect information on hygienic practices at different stages of the dairy value chain from a total of 765 smallholder producers and 22 primary dairy cooperatives.

The milk quality assessment includes preliminary quality tests (specific gravity or milk density, clot-on-boiling and alcohol tests), while the microbial analysis include Aerobic Mesophilic Bacteria, *Enterobacteriaceae*, Coliform, and Yeast and mould counts.

3. Hygienic conditions during production, processing, storage and marketing of milk and milk products

3.1 Milk production

3.1.1 Milking environment

In Ethiopia, there is no standard hygienic condition followed by producers during milk production. The hygienic conditions are different according to the production system, adapted practices, level of awareness, and availability of resources. In most of the cases under smallholder condition, the common hygienic measures taken during milk production especially during milking are limited to letting the calf to suckle for few minutes and/or washing the udder before milking. The quality of the water used for

cleaning purpose (to wash the udder, milk equipment, hands), however, is not secured (Yilma, 2003).

Maintaining the sanitary condition of milking area is important for the production of good quality milk. The drainage condition of the milking area, in this regard, is one of the most determinant factors. As observed during the current study, about 71% of the respondents had well drained and easy to clean barns. This is mainly attributed to the large proportion (80.4%) of the respondents from all the study areas that used housed type of barn for their crossbred cows. Since housed and well built barns can drain easily, it has positive correlation with overall hygienic conditions of a given milking environment rendering the production of better quality milk. However, the barns owned by about 29% of the respondents were observed to be not well drained and difficult to clean, which leads to poor quality milk production. It is therefore important that producers consider appropriate drainage conditions of the milking environment as an integral part of production hygiene to ensure the supply of safe and good quality milk and its derivatives. It is also essential to implement a regular barn cleaning scheme. Although, about 87% of the respondents cleaned their barn on daily basis, about 9% of them cleaned only once or twice a week, and the remaining 4% did not clean at all.

3.1.2 The cow and the milker

Cleaning the udder of cows before milking is important since it could have direct contact with the ground, urine, dung and feed refusals while resting. Not washing udder before milking can impart possible contaminants into the milk. Milk is highly nutritious; therefore spoilage as well as pathogenic microorganisms present in the dust, urine, dung and feed refusals, once get access, can easily multiply and deteriorate the quality of milk making it unsafe for consumption and unfit for further processing. As observed during the present study, over 31 and 14% of the respondents owning local and crossbred dairy cows, respectively, do not wash the cow's udder before milking. They rather let calves to suckle before milking. Such practice, however, cannot replace washing. Producers should therefore make udder washing a regular practice in order to minimize contamination and produce good quality milk.

About 39 and 36% of the respondents owning local and crossbred milking cows, respectively, reported to not use towel at all, while about 10 and 20% of local and crossbred cow owners, respectively, responded to use collective towel to clean the udder of two or more milking cows. Such practice, in addition to its effect on milk quality, can lead to cross contamination of udder health problems of milking cows and related complications. In the current study about 27% of the respondents reported to have encountered udder health problems and over 18% of them reported the problem to have occurred more than twice a year. To reverse the situation, producers spent 650 birr per crossbred and 242 birr per local milking cows per year as treatment cost. The reported milk disposal from infected udders was estimated to amount to 1056 birr per crossbred and 560 birr per local cows. The use of individual towel and following essential cleaning practices during milking is important for the production of good quality milk and need be practiced by all producers.

Milkers, in addition to keeping good personal hygiene, should be in good health during milk operation. In this study, about 94 and 96% of the respondents reported to wash their hands before milking their local and crossbred cows, respectively. Covering hair and dressing gown during milking and handling of milk and milk products are important practices milkers need to obey, which weren't observed in any of the farms visited.

3.1.3 Milking utensils

About 81 and 3.4% of the respondents used plastic and stainless equipment, respectively, while 6.6% of them used clay pot. Equipment used for milking, processing and storage determine the quality of milk and milk products. Producers need therefore pay particular attention for the type as well as cleanliness of milk equipment. Milking equipment should be easy to clean. Aluminum and stainless steel equipment are mostly preferred.

3.1.4 Source of water used for cleaning

Although, about 45% of the respondents reported to use tap water for cleaning purpose (udder, milk equipment and hand), about 19 and 16% of them reported to use river and ground water, respectively, while the remaining about 20% reported to use water from either of the aforementioned sources (Fig. 1). Moreover, about 60% of the respondents that reported to use water from non tap sources neither boil nor filter it before use (Fig. 2). When water from non tap sources is used for cleaning purpose, it is important that producers should at least filter and heat treat it before use.

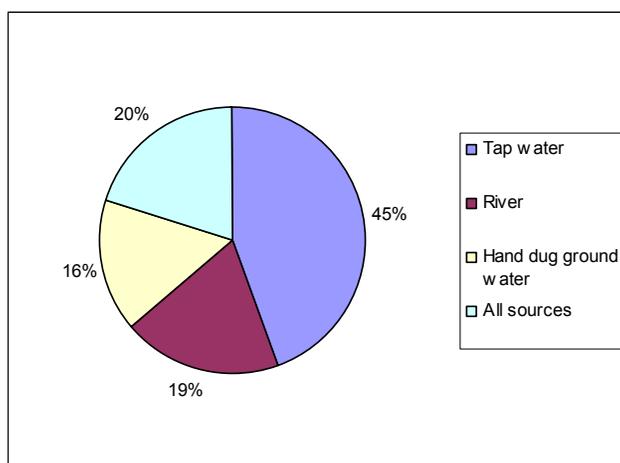


Fig. 1. Source of water used for cleaning purpose (cleaning udder, hands and milk equipment)

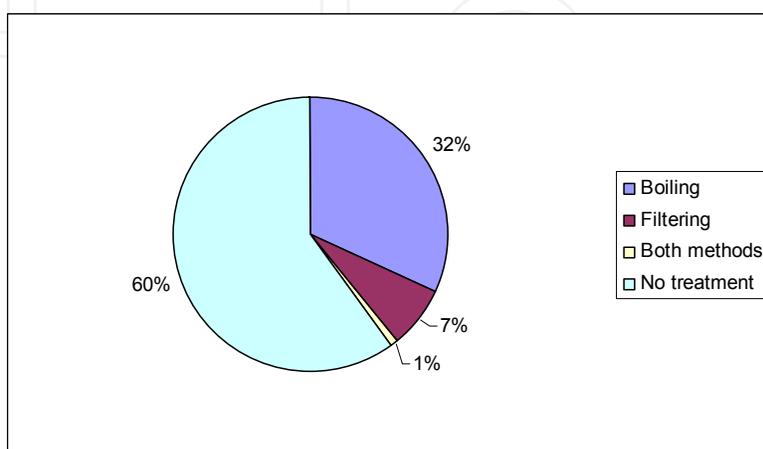


Fig. 2. Treatment of water from non tap sources before use (cleaning udder, hand, milk equipment)

3.2 Milk processing

Although various traditional milk processing and storage equipment are used in different parts of Ethiopia, clay pot is the most commonly available and used. Though not regularly practiced, 74.4% of the producers process milk into different products. Butter, *Ergo* and *Ayib* are the major fermented milk products, while clay pot is the most commonly used equipment under smallholder condition. Flow diagram of smallholder milk processing is presented in Fig. 3 and Fig. 4 depicts utilization of milk and milk products under smallholder condition. In Ethiopia, heating milk to sterilization temperature of above 100°C for 15 to 40 minutes followed by cooling and inoculation with known bacteria culture (starter) to achieve a controlled fermentation (O'Connor, 1994) is not practiced by smallholders.

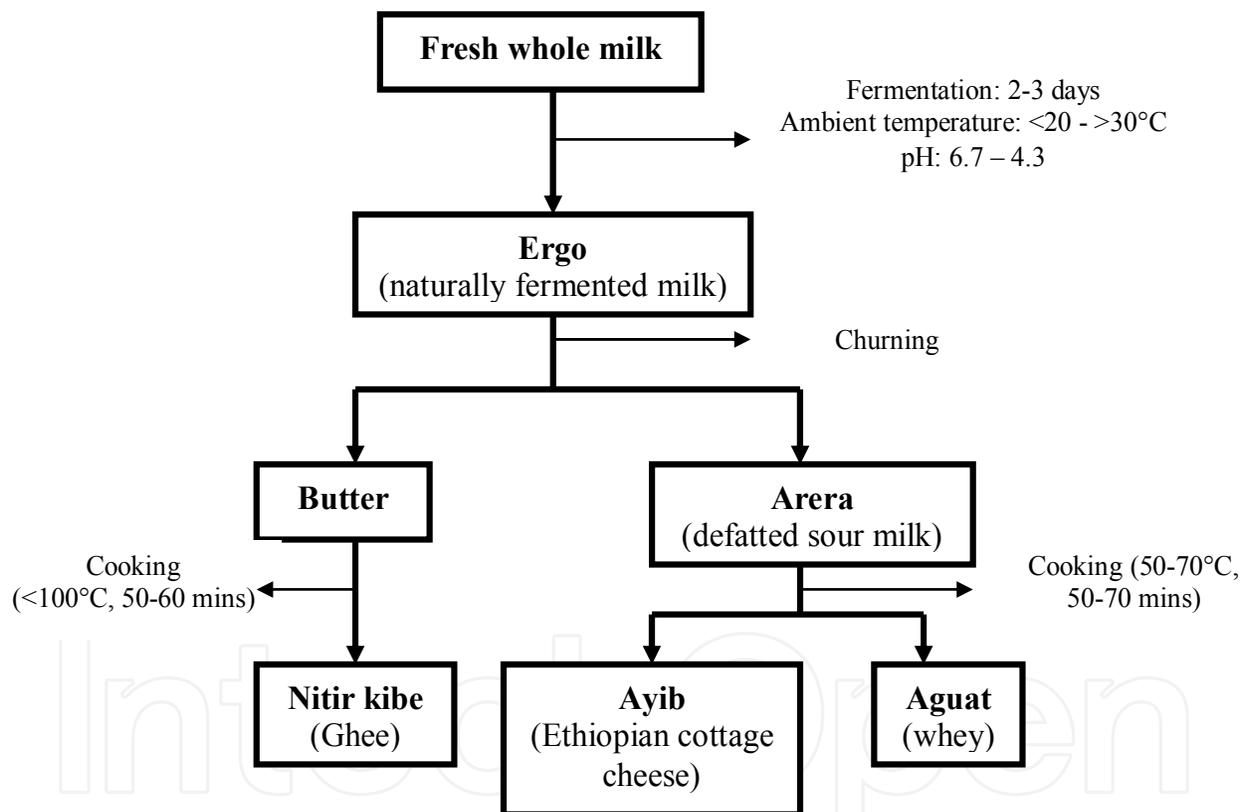
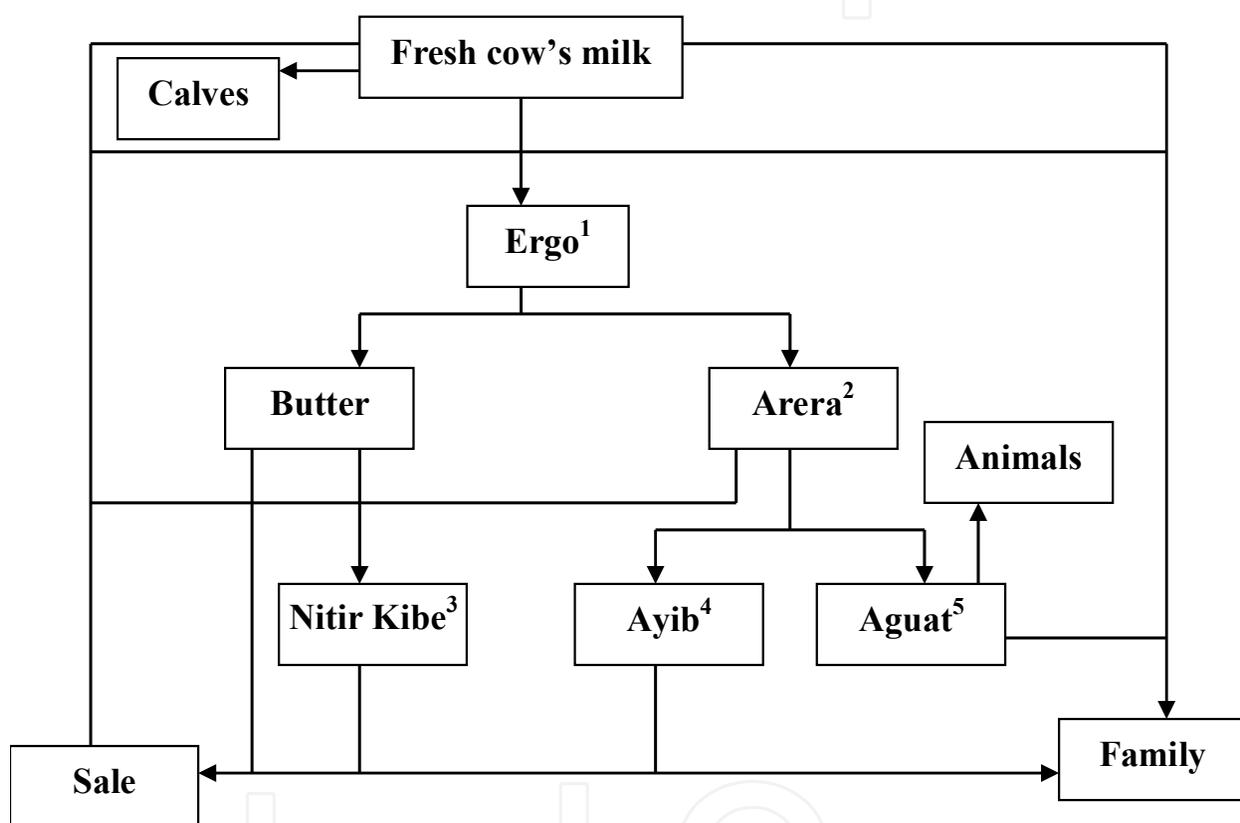


Fig. 3. Flow diagram of smallholder milk processing in the highlands of Ethiopia

Fermented milk is reported to have a storage stability of 15 to 20 days at a temperature of about 16 to 18°C (O'Connor, 1994). About 48% of the interviewees use clay pot for milk souring and/or churning for butter-making. In smallholder butter-making, microbial contamination can come from unclean surfaces, the butter maker and wash water. Packaging materials such as cups and leaves can also represent important sources of

contamination. Although washing and smoking the churn reduce bacterial numbers, traditional equipments are often porous and difficult to clean, therefore can serve as a reservoir for many organisms (O'Connor, 1994). Over 61% of the respondents in the study areas reported to use clay pot as a churn and for storage. *Ayib* is made by heating *Arera* or sour skim milk in a clay pot or another material on a low fire to about 40-50°C (FAO, 1990; O'Connor, 1993). In the current study, over 59% of the respondents reported to use clay pot for *Ayib*-making and storage.



¹Naturally fermented cow's milk, ²Defatted sour milk, ³Ghee, ⁴Ethiopian cottage cheese, ⁵whey

Fig. 4. Flow scheme of smallholder utilization of milk and milk products

Milk cooperatives sell fresh whole milk directly without further processing as well as process into more shelf stable products whenever there is no market for fresh whole milk. Unlike smallholder producers, cooperatives use hand operated cream separator and therefore, milk makes the basis of processing in cooperative settings (Fig. 5). Although, smallholder and cooperative milk processing differs, both produce similar major marketable products: butter and *Ayib*. Cooperatives also use manual churn for butter-making.

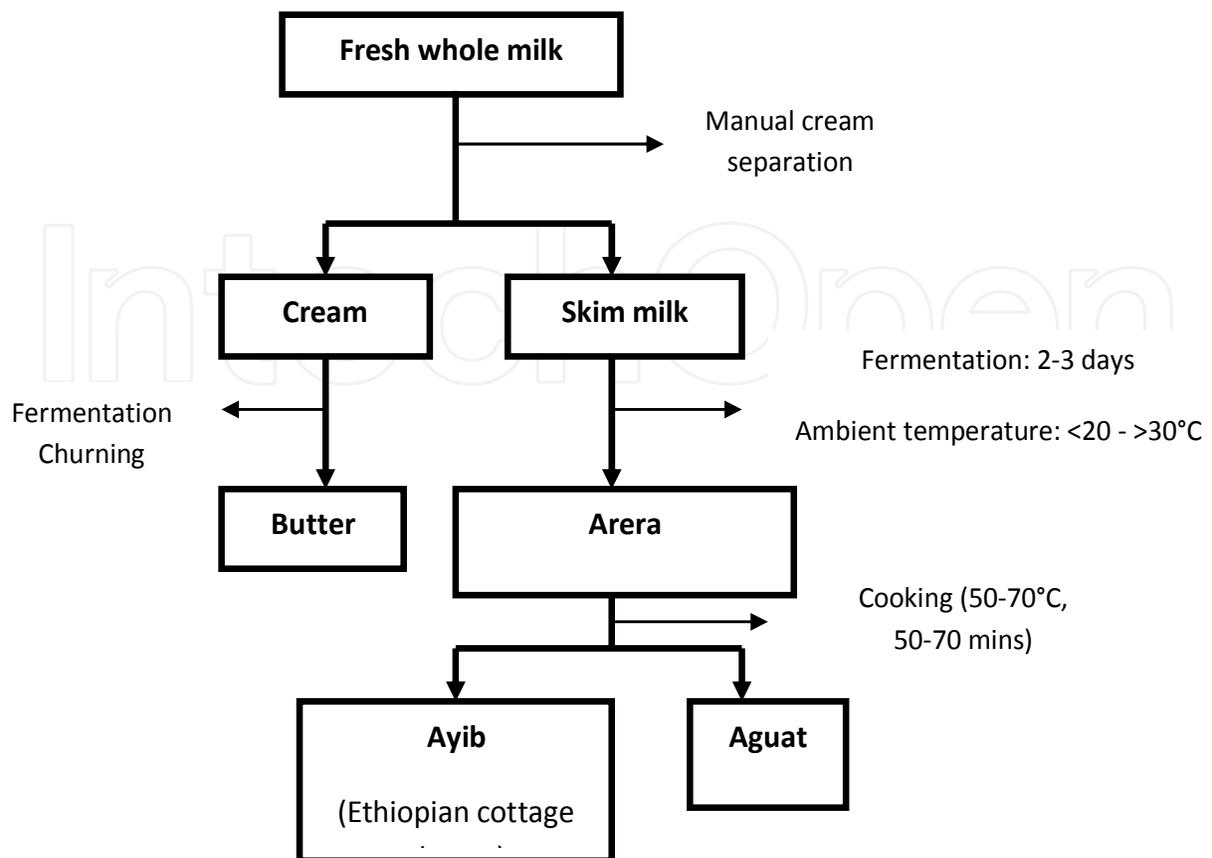


Fig. 5. Flow diagram of milk processing in cooperative centers in the highlands of Ethiopia

3.3 Storage

Milk products are generally more stable than fresh milk because they are more acidic and/or contain less moisture. Salt may also be added to milk products to prolong their shelf life. Applying principles of acidification, moisture reduction and salting (O'Mahony and Peters, 1987) can thus make milk products of good storage stability. All of the smallholder producers interviewed and about 82% of cooperatives stored their products at ambient temperatures. However, about 9% of the cooperatives have a refrigerator and the rest used cold water to store their products in cool conditions. Type of equipment used for different milk operations in the cooperative settings is presented in Table 1.

Purpose	N	Equipment used (frequencies, %)		
		Aluminum/Stainless steel	Plastic containers	Wooden containers
Milk collection	22	65.9	34.0	-
Milk storage	22	76.2	23.8	-
Cream storage	22	77.5	22.5	-
Butter storage	22	55.0	15.0	30.0
Cheese storage	22	88.2	11.8	-

Table 1. Equipment used for different milk operations in cooperative settings

3.4 Marketing of milk and milk products

There are basically two marketing systems in the central highlands of Ethiopia: formal and informal. In the formal system milk is collected at cooperative or private milk collection centers and transported to processing plants. In this system, there are somehow milk quality tests (alcohol and clot-on-boiling tests and density) up on delivery, and therefore the quality of milk is fairly secured. Producers supplying milk in this system pay a due emphasis in the production, storage and transportation of milk if their milk has to be accepted. In the informal system producers supply their surplus production to their neighbors and/or in local markets, either as liquid milk or in the form of butter and/or *Ayib* (O'Connor, 1992). In this system, the quality of milk and milk products is very poor mainly due to the prevailing situation where producers have limited knowledge of dairy product handling coupled with the inadequacy of dairy infrastructure such as electricity and clean water in the production areas.

In Ethiopia, there is no an operational hygienic regulation set for smallholder marketed dairy products. This indicates that the health of the dairy consuming community is not secured. This particularly holds true for *Ayib*, which is consumed with *Enjera* without farther treatment (Duteurtre, 1998). On open markets buyers of milk products practice organoleptic tests. The transaction of *Ayib* is particularly subject to such tests and it is uncommon that a buyer of *Ayib* is not tongue-testing the *Ayib* before buying it. This type of test is only partly associated with the effects of putrefactive microorganisms that can be detected by a simple tongue test. The presence of pathogenic microorganisms, however, cannot be detected by such tests.

There are reports that depict experiences of certain cooperatives around the Selale area (about 14%) (Yilma, 1999) that had a rewarding mechanism through better payment for good quality milk supplied. Such an approach encourages cooperative member and non-member farmers to be concerned about sanitary conditions during milk production and subsequent handling.

3.5 Major milk quality related constraints

Milk quality related constraints ranked during group discussions with dairy cooperatives are presented in Table 2. The major milk quality related constraints include: limited

Constraints	Rank
Limited awareness on hygienic handling	1 st
Shortage of capital	1 st
Lack of clean water	3 rd
Poor type of barn	3 rd
Hygiene of the milker	5 th
Lack of transport facilities	6 th
Mastitis (udder health problem)	7 th
Inappropriate materials used for milk production and handling	8 th

Table 2. Major milk quality related problems ranked using pair-wise comparison during group discussions

awareness on hygienic handling of milk and milk products, which could mainly be attributed to inefficient extension services; shortage of capital to purchase recommended equipment (milk containers, and processing and packaging materials); lack of clean water for sanitation purpose and poor condition of barn or milking area that is directly related to shortage of capital and limited awareness of its implication on milk quality.

4. Quality of milk and milk products

4.1 Density and freshness of products

Milk, at its normal state, has unique physico-chemical properties, which are used as quality indicators. The density of milk, among others, is commonly used for quality test mainly to check for the addition of water to milk or removal of cream. Addition of water to milk reduces milk density, while removal of cream increases it (O'Connor, 1994). The solid constituents of milk make milk an important food item from nutritional as well as processing point of view. Milk fat and protein are most important components of different varieties of most shelf stable milk products. All the 22 milk cooperatives used specific gravity test as an indicator of milk quality. The average specific gravity of 72 milk samples tested was 1.028 and 1.029 for Holetta and Selale areas, respectively (Fig. 6). These values fall within the range between 1.028 and 1.032 given to unadulterated milk (O'Connor, 1994). About 21% of the same samples checked with alcohol test were positive, while only 14% of the samples were positive for clot-on-boiling test. The results indicate that certain farmers deliver milk to collectors that has undergone fermentation that occurred either through long time elapsed between milking and delivery; mixing evening and morning milk; or use of insufficiently cleaned milk containers.

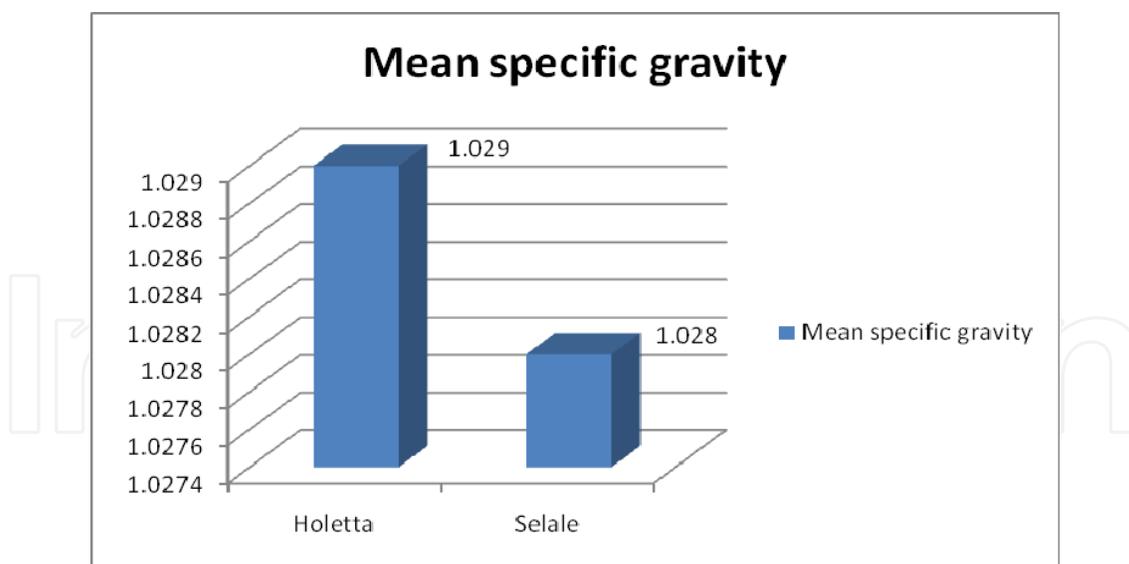


Fig. 6. Specific gravity/density of milk samples in Selale and Holetta areas

The mean pH values of whole milk ranged from 6.29 for Debre Birhan to 6.66 for Selale (data not presented). This variation and low pH may be attributed to the long time elapsed between milking and supply to collection centers. Three of the 24 samples of pasteurized milk checked with alcohol test were positive, while 5 of the samples were positive for clot-on-boiling test. These results are consistent with the results of pH values observed for the

same samples that ranged from the lowest 5.46 to the highest 6.14 with an overall mean value of 5.87. The relatively low pH of *Ergo*, ranging from 4.3 to 4.5 retards the growth of undesirable microorganisms, such as pathogens and spoilage bacteria, and enables its further storage (Gonfa *et al.*, 2001).

4.2 Microbial properties of milk and milk products

The microbial content of milk indicates the hygienic levels during milking that include cleanliness of the milking utensils, proper storage and transport as well as the wholesomeness of the udder of the individual cow (Spreer, 1998). The most commonly used microbial quality tests for milk and milk products include determination of total bacterial count (TBC) or standard plate count (SPC) and coliform count (CC). Estimation of yeast and mould counts is also useful for evaluating sanitary practices (O'Connor, 1994). Microorganisms can enter milk via the cow, air, feeds, milk handling equipment and the milker. Once they get into the milk their numbers increase rapidly. It is therefore more effective to exclude microorganisms than trying to control their growth once they get access into the milk.

There are varieties of traditionally fermented dairy products in Ethiopia, for which the exact type of desirable lactic acid bacteria responsible for fermentation is unknown due mainly to uncontrolled and spontaneous fermentation. Most of these products are produced by smallholder producers where access to the required dairy infrastructure is limited. Results of the present study and selected reports of relevant earlier research efforts on the microbial properties of locally produced milk and milk products that have been carried out in different parts of the country are briefly summarized below.

Source	No of Obs.	TBC	<i>Enterobacteriaceae</i>	Coliform	YMC
Overall mean	630	8.35	5.10	4.53	8.32
Whole milk	135	9.10	5.49	4.58	-
Ergo	105	9.49	4.95	4.51	8.38
Butter	105	6.67	4.95	4.58	8.32
Arera	75	9.35	4.94	4.65	-
Ayib	105	7.01	4.84	4.42	8.26
Skim milk	105	9.37	5.34	4.44	-

TBC: Total Bacterial Count; YMC: Yeast and Mould Count

Table 3. Overall bacterial and yeast and mould counts (log₁₀) per ml/g of milk and milk product samples collected from different sources (sites and producer groups)

Although there are slight variations between sample sources (locations/producer groups) in microbial counts, the figures observed in the present study are generally much higher than acceptable limits (Table 3). TBC is generally high in samples of whole milk, *Ergo* and skim milk. Counts of *Enterobacteriaceae* and coliform counts are higher than acceptable limits: *Enterobacteriaceae* <1 and coliform <10 cfu/ml for pasteurized milk, and coliform <100 cfu/ml for raw milk intended for direct consumption (Council Directives 92/46/EEC, 1992). The higher count in milk indicates substandard hygienic conditions practiced during production and subsequent handling. The high count in fermented milk products, however, can be partly explained by lactic acid bacteria.

4.2.1 Whole milk

Mean total bacterial counts ranged from 10.12 log cfu/ml of milk collected from Jimma to 8.30 log cfu/ml of milk sampled from Debre Zeit and Adama with the average value being 9.10 log cfu/ml. These values exceed the acceptable value of 10^5 cfu/ml for milk in most European countries (Council Directives 92/46/EEC, 1992; IFCN, 2006). Mean counts of *Enterobacteriaceae* were greater than 5 log cfu/ml and coliform counts greater than 4 log cfu/ml of milk sampled from all study sites.

In Ethiopia, milking animals are kept with the rest of the stock in a shade or enclosure during the night. Milking is done in the shade, grazing field in front of the homestead, or under a tree. However, as these areas are not generally kept clean enough, milking cows usually become soiled with dung and urine. Moreover, cleaning of the udder and hind quarters of the cow is not a common practice. This coupled with the unhygienic cleaning and handling of milk containers result in microbial contamination of milk (Tola, 2002; Gonfa *et al.*, 2001).

According to an earlier report, milk samples collected from smallholder producers in East Wollayta (Southern Ethiopia) had average total microbial count of 7.60 log cfu/ml (Tola, 2002). A total bacterial count ranging from 6.0 to 8.8 log cfu/ml in which 15% of the samples had a count equal or above 7.7 log cfu/ml in raw milk samples in Southern Ethiopia was also reported (Beyene, 1994). In another report, milk sampled from most of the dairy cooperatives operating in the country had total bacterial count of 10^8 cfu/ml (Francesconi, 2006). These values are much higher than the acceptable limits in different countries (10^4 to 10^5 cfu/ml) (IFCN, 2006). This implies that the sanitary conditions in which milk has been produced and handled are substandard subjecting the product to microbial contamination and multiplication. It is indicated that total bacterial count is a good indicator for monitoring the sanitary conditions practiced during production, collection, and handling of raw milk (Chambers, 2002). A good instance worth mentioning is a reduced total bacterial count observed in milk sampled from farmers who received training on hygienic milk production and handling, and who used recommended milk containers as compared to that produced by the traditional milk producers (control) (Tola, 2002; Nebiyu, 2008; Sintayehu *et al.*, 2008). A similar result was also reported for large-scale producers and research centers where there is a better access to dairy facilities as compared to small-scale producers (Yilma and Faye, 2006).

According to a report from Southern Ethiopia, raw cow's milk sampled from smallholder producers contained coliform counts of about 4.46 log cfu/ml (Tola, 2002). Similar counts were also observed in raw milk sampled from smallholder producers in the central highlands of Ethiopia (Yilma and Faye, 2006; Yilma *et al.*, 2007a). Higher counts of different species of *Enterobacteriaceae* were reported with *Escherichia coli* being the most abundantly isolated species (Yilma *et al.*, 2007a), which is a good indicator of recent fecal contamination (Bintsis *et al.*, 2008).

In a study focused on the identification of major bacterial species found in milk as it comes from the udder, it is reported that *Micrococci* represent the largest proportion followed by *Streptococci* and rods (O'Connor, 1994). In a separate study, *Staphylococci* and *Micrococci* are reported to be the most common udder-specific bacteria of environmental origin in milk samples taken directly from the udder (Godefaye and Molla, 2000).

Producer	Whole milk	Ergo*	Butter	Arera	Ayib	Skim milk
Total bacteria						
Smallholder farmers	8.87	9.48	6.86	9.35	7.16	-
Cooperatives	9.49	9.54	6.14	-	6.51	9.25
Overall mean	9.10	9.49	6.67	9.35	7.00	9.25
Enterobacteria						
Smallholder farmers	5.51	4.94	4.97	4.94	4.85	-
Cooperatives	5.45	4.98	4.90	-	4.82	5.30
Overall mean	5.48	4.95	4.95	4.94	4.84	5.30
Coliforms						
Smallholder farmers	5.59	4.48	4.60	4.65	4.44	-
Cooperatives	4.54	4.61	4.53	-	4.37	4.37
Overall mean	4.58	4.51	4.58	4.65	4.42	4.37
Yeast and mould						
Smallholder farmers	-	8.39	8.34	-	8.26	-
Cooperatives	-	8.34	8.27	-	8.27	-
Overall mean	-	8.38	8.32	-	8.26	-

*Ergo refers to fermented whole milk for smallholder farmers, while it refers to fermented skim milk for cooperatives

Table 4. Microbial count (log₁₀) per ml/g of milk and milk products categorized by sample source (producer type)

Total aerobic plate counts were 1.1×10^5 , 4×10^6 and 1.9×10^8 cfu/ml respectively for milk samples taken from milking bucket, storage container and processing plant on arrival (Godefaye and Molla, 2000). In the same study, mean coliform counts were reported to range from 1.3×10^4 cfu/ml (storage container) to 7.1×10^6 cfu/ml (on arrival at the processing plant). The hygienic quality of the milk from a collection center was poor with a mean total bacterial count of 1.3×10^7 cfu/ml. In another study, 4×10^7 and 1×10^9 cfu/ml total microbial counts were reported as lowest and highest values, respectively for raw milk samples at a processing plant in Addis Ababa. Of the total counts in raw milk, psychrophilic, thermophilic and thermophilic organisms made up 98.1, 1.4 and 0.5%, respectively.

4.2.2 Ergo – Naturally fermented milk

Ergo is made by natural fermentation of milk under ambient temperature, without the addition of starter cultures (Assefa *et al.*, 2008). The use of a portion of ergo from a previous batch as a starter in highland areas where ambient temperature is relatively low is reported (Kassa, 2008). This practice is technically adapted to overcome the effect of low ambient temperature, which slows down the growth of lactic acid bacteria (LAB) in the absence of starter culture thus prolongs the fermentation time. The temperature and duration of incubation varies from place to place depending on the prevailing environmental conditions. According to a previous report, five LAB genera were identified from *Ergo* that include *Lactobacillus*, *Lactococcus*, *Leuconostoc*, *Enterococcus* and *Streptococcus* (Assefa *et al.*, 2008). They also indicated the LAB species identified in *Ergo* to be *Streptococcus thermophilus*, *Strep. acidominus*, *Enterococcus faecalis* var. *liquefaciens*, *Strep. bovis*, *Strep. mitis*, *Strep. agalactiae*, *Lactococcus cremoris*, *Leuconostoc dextranicum*, *Leuc. lactis*, *Lactobacillus xylosus* and

Lact. lactis. The isolation of similar genera, and *Micrococci* and coliforms, which are present in low numbers was also reported (Gonfa *et al.*, 2001). An average LAB count of 7.68 log cfu/ml for *Ergo* samples collected from different producers in Addis Ababa and major cities around Addis Ababa was also reported (Yilma and Faye, 2006).

LAB are reported to have antimicrobial activities. The use of different LAB species to create a stationary phase for *Staphylococcus aureus* and a higher density of LAB in modeled starter culture could result in complete inhibition of the bacterium (Le Marc *et al.*, (2009). Another report also indicated that 12 LAB isolates from *Ergo* that include *Lactobacillus plantarum*, *Lactococcus lactis* ssp *cremoris*, *Lactococcus lactis* ssp *lactic*, *Lactobacillus acidophylus*, *Leuconostoc lactis*, *Pediococcus pentosace* and *Pediococcus* sp. have antimicrobial activities against different pathogenic microbes including *Shigella flexinery*, *Salmonella typhi*, *Escherichia coli* and *Staphylococcus aureus* (Assefa *et al.*, 2008).

TBC of *Ergo* was generally high ranging from 7.71 cfu/ml in samples collected from Sheno to about 10 cfu/ml in samples from Jimma. Average *Enterobacteriaceae* and coliform counts were greater than 4 cfu/ml of *Ergo* sampled from all study sites with differences between the lowest and highest counts ranging from 0.25 to 0.37 cfu/ml.

Mean yeast and mould counts observed in the current study exceeded 8 cfu/ml of *Ergo* sampled from all the sites considered. However, a lower value (2×10^5 cfu/ml) was reported (Gonfa *et al.*, 2001). Yeast and mould count of up to 4.6 log cfu/ml of fermented milk sampled from Southern Ethiopia was also reported (Beyene, 1994). These values are much higher than the acceptable value (<10 cfu/gm for yoghurt) (Mostert and Jooste, 2002). 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 the flavor of fermented milk, since different yeast species are able to assimilate different milk substrates (Gadaga *et al.*, 2000). Bacterial species namely *Klebsiella pneumoniae*, *Klebsiella oxytoca*, *Enterobacter cloacae*, *Citrobacter freundii* and *Enterobacter sakazakii* were isolated from *Ergo* samples collected from smallholder producers in the central Ethiopia (Yilma *et al.*, 2007a). Coliform count averaging at 6.57 log cfu/ml was reported for *Ergo* samples (Yilma and Faye, 2006). Lower values were also observed in which 75% of the samples showed coliform count less than 4.4 log cfu/ml (Beyene, 1994). However, the same author also reported TBC of greater than 8.6 log cfu/ml for 3/4th of fermented milk samples collected from three villages in Southern Ethiopia and coliform counts of higher than 4.4 log cfu/ml in 15% of two fermented milk varieties.

The common traditional milk processing techniques involve smoking of processing utensils using embers of *Olea africana*. This smoking practice is reported to be beneficial to keep better quality of *Ergo* through its inhibitory effect on spoilage and pathogenic organisms. For instance, the inhibitory effect of smoking on *Listeria monocytogenes* was reported (Ashenafi, 1994). The effect of lower pH of *Ergo* in controlling the proliferation of undesirable microorganisms is more effective after 24 hours of incubation. However, at this time, the *ergo* is considered to be too sour for direct consumption since *ergo* coagulates within 24 hours and preferably consumed at this time for its good flavor (Ashenafi, 2006). Accordingly, the same author recommended that milk should be boiled beforehand and a small amount of 3-days-old *Ergo* that is normally free from pathogens but contains enough LAB should be inoculated to initiate fermentation.

4.2.3 Kibe – Traditional butter

Different studies on various aspects of traditional butter-making in Ethiopia have been undertaken in different parts of the country. Traditional butter-making is based on sour milk that has been accumulated over a few days commonly in a clay pot. Once the amount of the accumulated sour milk justifies churning, the sour milk is mixed thoroughly by using a wooden stick with 3 to 5 finger-like projections at one end (*mesbekia* in amahric) then churned using different techniques until butter granules are formed.

Mean total bacterial counts ranged from 6.18 cfu/g in butter samples collected from Selale area to 7.25 cfu/g in samples from Sululta. These values are higher than the acceptable limit of 5×10^4 cfu/g (Mostert and Jooste, 2002). Average *Enterobacteriaceae* and coliform counts were greater than 4 cfu/g of butter sampled from all study sites both of which are higher than the acceptable value of <10 cfu/g (Mostert and Jooste, 2002). Mean yeast and mould counts observed in the current study exceeded 8 cfu/g of butter sampled from all the sites considered.

TBC of 3.15×10^7 and the presence of high variability among samples depending on the sources were reported (Mamo, 2007). Samples collected from open markets and rural producers, for instance, had higher counts as compared to that obtained from dairy farms and urban producers. Coliform counts ranging from 1.92 to 4.5 log cfu/gm of butter are reported (Mamo, 2007; Asfaw, 2008; Yilma *et al.*, 2007a). These differences could be attributed to the wide variation in hygienic handling during milking, processing, storage and transport to market. *Klebsiella pneumoniae*, *Klebsiella oxytoca*, *Enterobacter cloacae*, *Citrobacter freundii*, and *Esherichia coli* were isolated from *ergo* samples collected in the central Ethiopia (Yilma *et al.*, 2007ab), and these microbes are considered to be pathogenic and spoilage (Walstra *et al.*, 2006). On the other hand, yeast and mould counts ranging between 4.3 and 6.86 log cfu/g of butter sampled from Wollayta area are reported (Asfaw, 2008). Average yeast and mould count of 4.5×10^7 cfu/g of butter was also reported (Mamo, 2007). Higher values are observed (Yilma *et al.*, 2005) that varied depending on the type of producer where lower counts were observed for butter sampled from research centers and small-scale producers than that from large-scale producers. TBC of fresh butter sampled from rural and public butter markets in Addis Ababa ranged from 6.2×10^4 to 1.86×10^8 per gram of butter and coliforms were found in all samples that indicate poor hygienic practices (ILCA, 1992). These high deviations from the acceptable value of 10 cfu/gm (Mostert and Jooste, 2002) indicate substandard handling conditions at all stages in the milk chain.

4.2.4 Arera – Defatted sour milk

Average counts of total bacteria, *Enterobacteriaceae* and coliforms were greater than 9, 4.7 and 4.2 cfu/ml, respectively of *Arera* sampled from all study sites both of which are higher than the acceptable value of <10 cfu/gm (Mostert and Jooste, 2002). Traditionally produced *Arera* sampled from Wollayta area had total bacterial count of about 9 log cfu/ml (Nebiyu, 2008). The same author also reported coliform count of 4.86 log cfu/ml. Different species of bacteria were identified in *Arera* samples collected during both dry and wet seasons, which include: *Klebsiella pneumoniae*, *Klebsiella oxytoca*, *Enterobacter cloacae*, *Enterobacter sakazakii*, *Esherichia coli* and some species of *Salmonella* (Yilma *et al.*, 2007a).

4.2.5 Ayib – Ethiopian cottage cheese

Mean TBC ranged from 6.46 cfu/g in *Ayib* samples collected from Arsi and Selale area to 7.87 cfu/g in samples from Sululta with the overall mean being 7.01 cfu/g. Average *Enterobacteriaceae* and coliform counts were greater than 4 cfu/g of *Ayib* sampled from all study sites. Mean yeast and mould counts observed in the current study exceeded 8 cfu/g of *Ayib* sampled from all the sites considered.

Ayib samples contained high numbers of mesophilic bacteria, *Enterococci*, and yeasts (Ashenafi, 2002). The author also reported aerobic mesophilic bacterial counts of over 10^8 cfu/g for more than 90% of the samples collected in Southern Ethiopia. Works undertaken to identify bacterial species in *ayib* samples reported *Klebsiella pneumoniae*, *Klebsiella oxytoca*, *Enterobacter cloacae* (Yilma *et al.*, 2007b), *Staphylococcus aureus* and *Bacillus cereus* (Ashenafi, 2002).

Several earlier works carried out in different parts of the country reported coliform counts of *ayib* samples that ranged between 2 log cfu/gm (Ashenafi, 2002, 2006) and 5.68 log cfu/gm (Yilma *et al.*, 2005) with differences being a function of source of samples and handling conditions. Coliform counts varied among samples collected from different producers where samples from research centers had lower coliform counts (4.85 log cfu/gm) as compared to samples from large-scale (5.68 log cfu/gm) and small-scale (5.48 log cfu/gm) farms showing variations in the hygienic conditions practiced among the different producers (Yilma *et al.*, 2005). However, in all cases values are higher than the acceptable level of <10 cfu/gm (Mostert and Jooste, 2002) indicating the poor hygienic conditions practiced during processing and handling.

Ayib samples collected from an open market in Awassa showed high numbers of mesophilic bacteria, enterococci and yeasts (Table 19). More than 90% of the samples had aerobic mesophilic counts of $\geq 10^8$ cfu/g while more than 75% of the samples had yeast counts of $\geq 10^7$ cfu/g, and over 85% contained *Enterococci* in numbers of $\geq 10^7$ cfu/g. The majority of the samples had mould and lactic acid bacteria counts of 10^5 cfu/g or higher, spore-formers of about 10^4 and psychrotrophs of about 10^6 cfu/g. Over 32% had coliform counts of more than 10^2 /g and about 27% contained fecal coliform loads of more than 10^2 /g. *Bacillus cereus* and *Staphylococcus aureus* were isolated in 63% and 23% of the samples, respectively, but at low numbers (10^2 to 10^3 cfu/g) (Ashenafi, 1990).

4.2.6 Domestic commercial pasteurized milk

Mean total bacterial counts ranged from 6.60 to 7.54 \log_{10} cfu/ml of domestic pasteurized milk collected from different kiosks and supermarkets in Addis Ababa with the average value being 7.28 \log_{10} cfu/ml (Table 5). Mean counts of coliform bacteria and *Enterobacteriaceae* were 2.87 and 3.69 \log_{10} cfu/ml, respectively. These values are much higher than the acceptable values. As presented in microbiological safety limits for major milk products in community legislation in force by the European Commission, the maximum limit for total bacterial and coliform counts in pasteurized milk intended for drinking is 5×10^5 and 5 cfu/ml, respectively, while *Enterobacteriaceae* count should be <1 cfu/ml and pathogenic microorganisms should not be detected in 25 ml of the product (Council Directives 92/46 EEC, 1992).

The pasteurized milk samples considered in the present study were between 5 to 2 days before the expiry date as indicated on the packaging materials. Although, the high total

bacterial count observed in the current study can partly be attributed by lactic acid bacteria, which can be explained by the low mean pH value of 5.87, the higher counts of coliform bacteria and *Enterobacteriaceae* imply that there was a problem either in the pasteurization process or there occurred post pasteurization contamination during packaging. Protection from post-pasteurization contamination before the milk product is packaged is a critical factor in achieving a safe food. Ingredients added after pasteurization of the milk portion of the food can be a source of pathogens. The control of potential sources of contamination can be addressed by following production practices based on Good Manufacturing Practices.

Pasteurized milk had mesophilic aerobic counts of 7×10^5 cfu/ml as it left the pasteurizing unit (Mahari and Gashe, 1990). According to the same source, psychrophilic, thermophilic and thermophilic organisms constituted 53.0, 39.5 and 7.5%, respectively and the isolates belonged mostly to the genera *Bacillus*, *Streptococcus*, *Lactobacillus*, *Arthrobacter*, *Alcaligenes*, *Aeromonas* and *Pseudomonas*. Cocci were more predominant than rod-shaped bacteria and of the rod-shaped bacteria 73% were gram-negative. As indicated by the same authors, utensils holding the raw and pasteurized milk and plastic sheets used for bagging the pasteurized milk were reported to contribute for the high bacterial count, which were either thermophilic or thermophilic.

Pasteurized milk sample*	No. of obs.	Count, Log10 cfu/ml		
		TBC	CC	EntC
A	4	7.28	3.18	3.58
B	4	6.60	3.28	3.94
C	4	7.47	3.26	4.26
D	4	7.37	2.34	3.63
E	4	7.54	2.77	3.68
F	4	7.42	2.40	3.05
Overall mean	24	7.28	2.87	3.69

*Different letters represent different brands of pasteurized milk marketed in Addis Ababa; TBC: Total Bacterial Count; CC: Coliform Count; EntC: *Enterobacteriaceae* Count; cfu/ml: Colony Forming Units per millilitre

Table 5. Microbial quality of domestic commercial pasteurized milk sampled from different kiosks and supermarkets in Addis Ababa

5. Critical control points in the milk chain

As with hygiene and food safety, the issue of quality has been growing prominently in recent years and the optimum approach to these two areas is remarkably similar. Providing quality assured products to the consumer has traditionally relied on quality control of finished products, that is, a set of procedures to test and analyze the product to ensure it conforms to the required specification. This approach has drawbacks that include incidents of food poisoning in spite of quality control procedures, less effective as microorganisms are not evenly distributed in products, and high cost of rejected products as the quality control is based solely on finished product testing. This is one reason why, developments in quality management have focused on the prevention of defects in the first place (through effective design and hazard elimination) rather than trying to measure defects once the product has been manufactured. Applying this approach to hygiene has led to the development of preventive

Quality Assurance (QA) systems. Hazard Analysis and Critical Control Point (HACCP) in particular is employed in the identification of stages in the food chain where spoilage as well as pathogenic microorganisms can enter, survive and proliferate in the food and managing these as the key control strategy rather than relying on testing end products (IDF, 1994).

In the Ethiopian smallholder context, six Critical Control Points (CCPs) where milk and milk products can be contaminated can be identified (Fig. 7). These include:

- i. *During milk production:* During milking, contamination can come from the cow, the milker, utensils used for milking, storage and filtering the milk, and the barn or the milking environment.
- ii. *During fermentation:* Milk containers used for fermentation, wash water of poor quality used, ingredients added with the intention of improving the flavor of the final product can represent potential sources of contamination.
- iii. *During churning (butter-making):* Churns and warm water added to facilitate the churning process (speed-up butter recovery) can be possible sources of contamination.
- iv. *During Ayib-making:* Low cooking temperatures that may not be enough to kill spoilage as well as pathogenic microorganisms can be considered as an important point for the poor quality of the final product. Other potential sources of microbial contamination include: materials used for *Ayib*-making, other utensils such as that used for draining the whey or ladling out the *Ayib*, and filtration.
- v. *Packaging/storage of butter and Nitir Kibe/ghee:* Potential sources of contamination here include: product container/packaging, high keeping temperature, and poor personal hygiene of people handling the product.
- vi. *Packaging/storage of Ayib:* Potential sources of contamination here are similar with that under v above.

CCPs at dairy cooperatives are summarized in Fig. 8:

- i. *The milk/reception:* The raw material milk can be contaminated via the cow; the milker; the barn; utensils used for milking, filtering, storage (at farm and cooperative center) and transport.
- ii. *During cream separation:* Contamination at this point can come from the separator, wash water, personnel, and environment.
- iii. *During fermentation of skim milk:* Containers used for fermentation, poor quality wash water, personnel and the environment represent potential sources of contamination.
- iv. *During churning (butter-making):* Contamination at this point can come from the churn (container), personnel, wash water, and environment.
- v. *During Ayib-making:* Low cooking temperatures that may not be enough to kill spoilage as well as pathogenic microorganisms can be considered as an important point for the poor quality of the final product. Other potential sources of contamination include: materials used for *Ayib*-making, other utensils such as that used for draining the whey or ladling out the *Ayib*, and filtration.
- vi. *Packaging/storage of butter:* Potential sources of contamination here include: product container/packaging, high keeping temperature, poor personal hygiene of people handling the product, and environment.
- vii. *Packaging/storage of Ayib:* Potential sources of contamination here are similar with that under vi above.

The aforementioned critical points of contaminations can be considered for making improvement interventions.

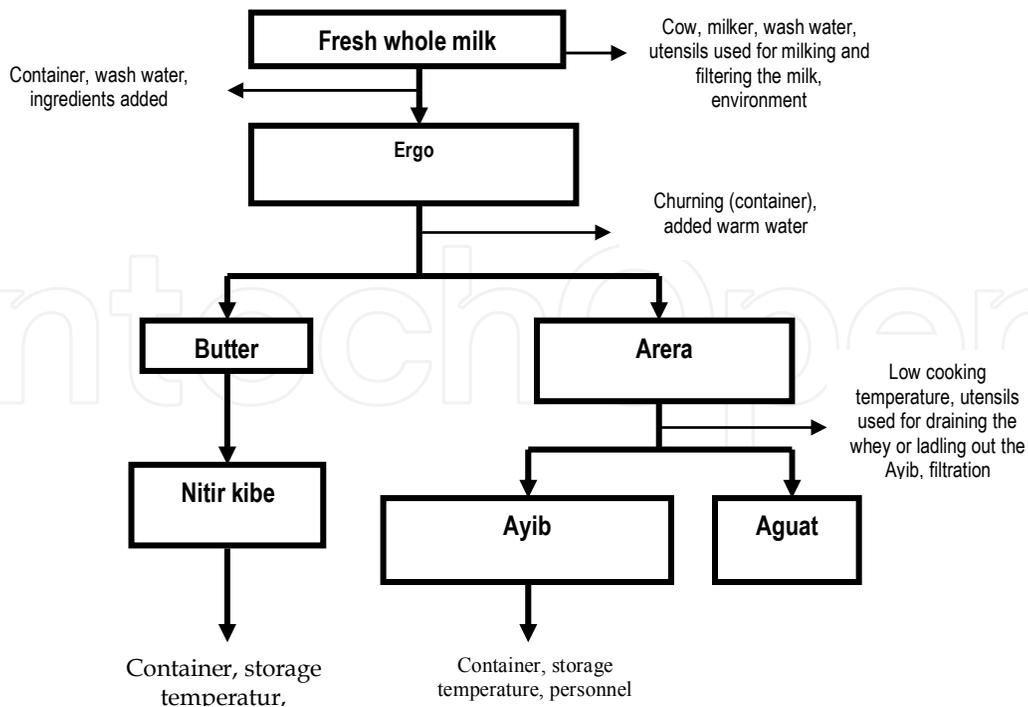


Fig. 7. Flow scheme of critical points of microbial contamination during traditional milk processing in the central Ethiopian highlands

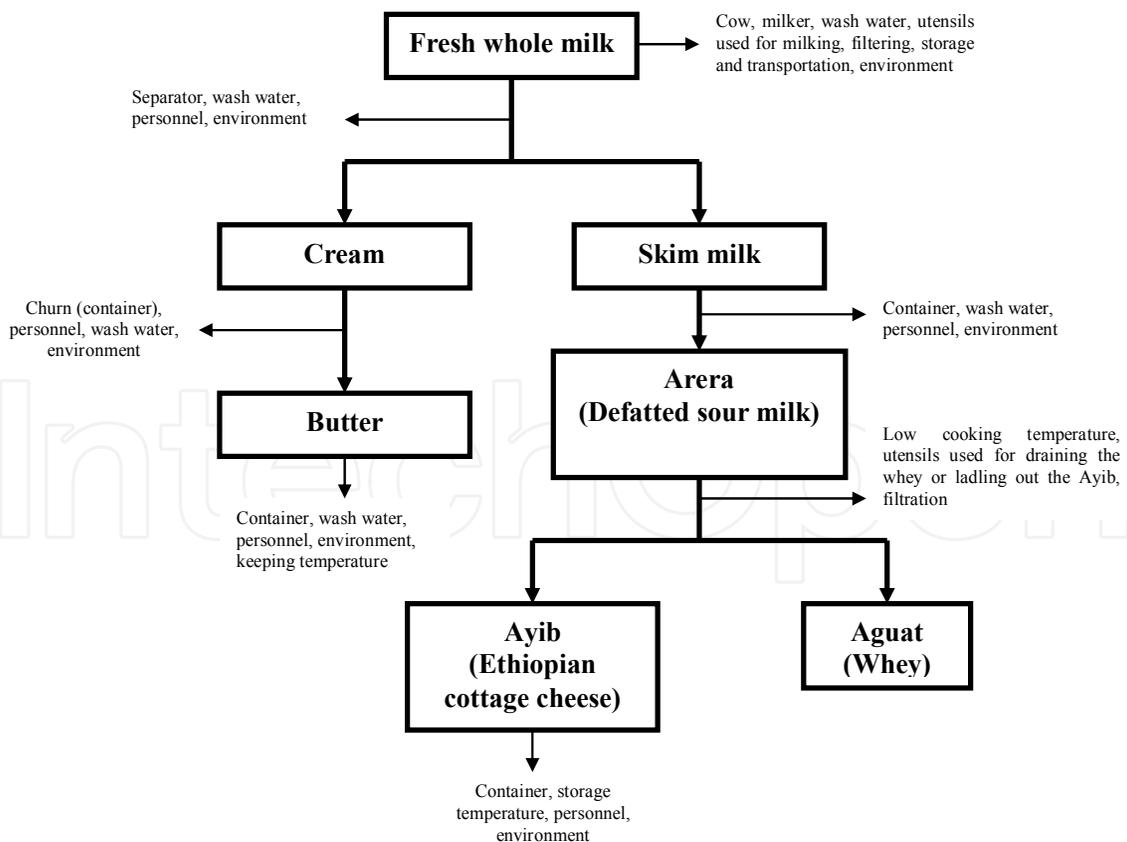


Fig. 8. Flow scheme of critical points of microbial contamination of milk and milk products at cooperative centers in different parts of Ethiopia

6. International quality standards practiced in different countries

As food safety and quality are a growing concern all over the world, different organizations in many countries implement quality control programs and established quality standards for all food items including animal products to ensure the health of the consumer. Health hazards to the consumer are often grouped into microbiological, physical and chemical (FDA, 2004). A microbial criteria stipulate that a type of microorganism, groups of microorganisms, toxin produced by a microorganism must either not be present at all, be present in only a limited number of samples, or be present at less than a specified number or amount in a given quantity of a food ingredient (NRC, 1985).

Different microbiological tests are used to indicate the hygienic condition of manufacturing of a given product. Coliform count provides an indication of unsanitary production practices and/or mastitis infection. A count less than 100 Colony Forming Units (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 will be consumed directly (Jones and Sumner, 1999; Ruegg, 2003). Estimation of the total bacteria count is the procedure used to measure the general sanitary quality of milk. The number of bacteria in aseptically drawn milk varies from animal to animal and even from different quarters of the same animal. On average, aseptically drawn milk from healthy udders contains between 500 and 1000 bacteria ml⁻¹. High initial counts (>10⁵ bacteria ml⁻¹) are evidence of poor production hygiene (O'Connor, 1994). 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).

Legal and voluntary bacteriological standards vary widely from country to country and there are different standards for different groups and species of microorganisms specific to specific products. Standard plate count (SPC) values for raw milk can range from <1000ml⁻¹, where contamination during production is minimal, to >1 × 10⁵ml⁻¹. Consequently, high initial SPC values (>10⁵ml⁻¹) are evidence of serious hygienic problem during production, likewise SPC values of <2×10⁴ml⁻¹ reflect good sanitary practices (IDF, 1994).

Somatic Cell Count/ml	Drug residue	Country	Source
< 7.5 × 10 ⁵	Absent	USA	IFCN, 2006; CDFA, 2008
< 4.99 × 10 ⁵	Absent	Canada	IFCN, 2006; CDFA, 2008
< 4 × 10 ⁵	Absent	France	IFCN, 2006; CDFA, 2008
< 4 × 10 ⁵	Absent	Sweden	IFCN, 2006; CDFA, 2008
< 10 ⁶	Absent	Russian	IFCN, 2006
< 6 × 10 ⁵	Absent	Israel	IFCN, 2006
< 4 × 10 ⁵	Absent	South Africa	IFCN, 2006
< 7 × 10 ⁵	Absent	Brazil	IFCN, 2006
< 5 × 10 ⁵	Absent	China	IFCN, 2006
< 2.5 × 10 ⁵	Absent	Australia	IFCN, 2006

Table 6. Commonly used safety limits of somatic cell count and drug residue for raw milk employed in selected countries

In many countries, a standard for Grade 'A' raw milk is an SPC of <10 ml⁻¹ for milk intended for heat treatment before consumption or further processing. For milk that is to be

Milk product	Microorganism	Maximum limit (cfu/ml or g)
Raw cow's milk intended for processing	Total bacteria	10 ⁵
	<i>Staphylococcus aureus</i>	2 x 10 ³
Raw cow's milk intended for direct human consumption	<i>Salmonella</i>	Absent in 25g
	<i>S. aureus</i>	5 x 10 ²
	Total bacteria	5 x 10 ⁴
Pasteurized drinking milk	Pathogenic microorganisms	Absent in 25g
	Coliforms	5
	Total bacteria	5 x 10 ⁵
UHT milk and sterilized milk	Total bacteria	100
Cheese made from raw and thermized milk	<i>Listeria monocytogenes</i>	Absent in 1g hard cheese or in 25g other cheese varieties
	<i>Salmonella</i>	Absent in 1g
	<i>S. aureus</i>	10 ⁴
	<i>E. coli</i>	10 ⁵
Soft cheese made from heat treated milk	<i>L. monocytogenes</i>	Absent in 25g
	<i>Salmonella</i>	Absent in 1g
	<i>S. aureus</i>	10 ³
	<i>E. coli</i>	10 ³
	Coliforms	10 ⁵
Fresh cheese	<i>L. monocytogenes</i>	Absent in 25g
	<i>Salmonella</i>	Absent in 1g
	<i>S. aureus</i>	100
Butter	<i>L. monocytogenes</i>	Absent in 25g
	<i>Salmonella</i>	Absent in 1g
	Coliforms	10
Powdered milk and milk based products	<i>L. monocytogenes</i>	Absent in 1g
	<i>Salmonella</i>	Absent in 1g
	<i>S. aureus</i>	100
	Coliforms	10
Frozen milk based products	<i>L. monocytogenes</i>	Absent in 1g
	<i>Salmonella</i>	Absent in 1g
	<i>S. aureus</i>	100
	Coliforms	100
	Total bacteria	10 ⁵
Liquid milk based products	<i>L. monocytogenes</i>	Absent in 1g
	<i>Salmonella</i>	Absent in 1g
	Coliforms	5

Source: Council Directives 92/46 EEC (1992)

Table 7. Microbiological safety limits for selected milk products in community legislation in force by the European Commission

consumed raw, a more stringent standard is generally required because consumers of raw milk are at a greater risk for contracting a milk-borne illness such as salmonellosis. In some countries, standards adopted may depend on whether milk is refrigerated or merely water-cooled. For example, in North America, SPC values of <10⁶ ml⁻¹ or equivalent are

acceptable for manufacturing grade 'A' milk. In contrast, in the UK no distinction is made between raw milk marketed for further processing and that marketed for fluid consumption (Chambers, 2002). Although on-farm testing and independent laboratory testing do not guarantee food safety, they are generally accepted means to monitor milk quality. In dairy developed countries, buying raw milk from a Grade 'A' herd assures that the milk is tested for pathogens on a regular basis therefore is fit for further processing and consumption (Walstra *et al.*, 2006). Quality related safety limits practiced in selected countries are presented in Table 6, while Table 7 depicts microbiological safety limits for selected milk products in community legislation in force by the European Commission.

7. Conclusion

The microbiological properties of marketed milk and milk products in different parts of Ethiopia are generally below standards. This is mainly due to unhygienic conditions at one or more of the stages in the dairy value chain from farm to table, which in turn might be attributed to inadequate dairy infrastructure coupled with limited knowledge on the hygienic production and handling of milk and milk products. Based on experiences from a number of countries, it is likely that problems with effective translation of knowledge to practice, rather than incomplete knowledge per se, are the more important constraints to national progress towards improved milk quality.

Currently, the Ethiopian dairy sector is developing and the involvement of the private sector is at the increase. Moreover, consumers are increasingly concerned about the quality of products and the production conditions. A concerted effort towards improving the qualities of milk and milk products and contributing to the betterment of the Ethiopian formal milk business is essential. This benefits both the producer through allowing entering into the competitive market and bringing increased income from the sale of quality products, and the consumer through creating access to products of acceptable quality.

From experiences of a number of countries, putting functional quality standards, quality control system and payment system based on quality in place resulted not only in improved quality of marketed milk but also the volume of milk delivered to collection centers and dairies. It is important that quality standards for milk and major milk products for Ethiopia, should take into consideration factors such as the prevailing conditions of facilities and infrastructures required for dairy development; the existing quality standards currently in use in different countries; and the actual qualities of milk and milk products being marketed in different parts of Ethiopia. Such an approach will improve the Ethiopian formal milk business.

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