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RESEARCH ARTICLE

THE MICROBIOLOGY OF ETHIOPIAN MILK AND MILK PRODUCTS: REVIEW

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ABSTRACT

Milk is a translucent white liquid produced by mammary glands of mammals. The quality of milk and its product is highly affected because it is an excellent and perfect culture medium for the growth of many kinds of micro-organisms. The objective of the review was to assess the safety of milk and its products with respect to food-borne diseases, losses and improving quality and to suggest well developed milk marketing system as a majority of small scale producers' access to market. Accordingly, In Ethiopia, milk marketing system is not well developed and for the majority of small scale producers, access to market is limited. The amount produced is subjected to high post-harvest losses. Losses of up to 20–35% have been reported for milk and its products from milking to consumption. Such loses are mainly attributed to highly perishable nature of milk and mishandling, contamination during milking and further handling coupled with long storage time at high ambient temperature before consumption; inefficient transportation and distribution systems; inefficient processing technologies; inadequate fresh milk outlet; and spillage losses during milking. The total bacterial count obtained from raw milk collected from Yabello District of Borena zone is generally high compared to the acceptable level of 1 x 10^5 bacteria per ml of raw milk. The total bacterial count obtained from dairy cooperative milk collection centers was significantly higher ($P < 0.05$) than milk samples collected from hotels, small shops/kiosks and small scale milk producers which might be due to further contamination of the milk during transportation, use of poorly cleaned milk containers and absence of cooling systems at milk selling points. It was concluded that the microbial quality of Ethiopian milk and milk products is not to the standard and subjected to post-harvest and pre-consumption spoilage which result in milk borne illness. Therefore, awareness on hygienic production and handling of milk and products and adequate production and processing technologies should be fulfilled.

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INTRODUCTION

Milk is a translucent white liquid produced by mammary glands of mammals. It is the most perfect single balanced food of high biological value and food of outstanding interest which has been taken by humans since the earliest pre-historic times which still forms the basis of most nations' economics (Mesfine *et al.*, 2015). It provides the primary source of nutrition for young mammals before they are able to digest other types of food (Olatunji *et al*., 2012). It contains almost all ingredients of food in right proportion in any easily digestible form (Mesfine *et al.*, 2015).

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Being a nutritious food, raw milk is an excellent growth medium for microorganisms, originating from either mastitis or from the environment during milking or milk handling process (Pospescu and Angel, 2009). The quality of milk and its product is highly affected because it is an excellent and perfect culture medium for the growth of many kinds of micro-organisms (Chatterjee *et al*., 2006 and Lingathurai, 2009). Its water content, a pH which is close to neutral and a diversity of nutrients, lead milk and milk products to microbial deterioration (Barros *et al*., 2011). The quality of raw milk can be judged by microbial load as per the guide lines of International Dairy Federation. The production of milk having Standard Plate Count of 10^4Cfu/ml reflects good hygienic practices while high initial Standard Plate Count of more than 10^5 CFU/ml are evidence of serious faults in production hygiene (IDF, 1990). Fresh milk drawn from a healthy cow normally contains bacterial load of less than 10^3 CFU/ml (Chatterjee *et al.*, 2006 and Lingathurai, 2009). The bacterial

load may increase up to 100 fold or more once it is stored for some time at ambient temperature (Lingathurai, 2009). Bacteria that mostly grow in milk are Lactobacillus, Streptococcus, Coliforms, Staphylococcus and Micrococcus spps (Torkar K.G. and Teger S.G., 2008) of which *Escherichia coli*, *Salmonella tyhpi, Pseudomonas aeruginosa and Staphylococcus aureus* are the fast rate in milk (Murinda *et al.,* 2004 and Oliver *et al*., 2005). The microbial load of milk and milk product is a major factor in determining its quality. It indicates the hygienic level exercised during milking, cleanliness of the milking utensils, condition of storage, manner of transport, cleanliness of the udder of individual animal as well as hygienic condition during milk product production (Torkar and Teger, 2008). The growth of microorganisms in milk results in spoilage of milk and milk products which brings infections or intoxications to consumers. Contaminated raw milk and milk products may act as a source of many harmful bacteria leading to various diseases, such as undulant fever, salmonellosis, dysentery and tuberculosis (Murinda *et al*., 2004 and Oliver *et al*., 2005).

The safety of milk and its products with respect to food-borne diseases is of great concern around the world. This is most common in developing countries where production of milk and various milk products takes place under unsanitary conditions and poor production practices (Yilma and Faye, 2006). In Ethiopia, milk marketing system is not well developed and for the majority of small scale producers, access to market is limited. The amount produced is subjected to high post-harvest losses. Losses of up to 20–35% have been reported for milk and its products from milking to consumption (Getachew, 2003). Such loses are mainly attributed to highly perishable nature of milk and mishandling, contamination during milking and further handling coupled with long storage time at high ambient temperature before consumption; inefficient transportation and distribution systems; inefficient processing technologies; inadequate fresh milk outlet; and spillage losses during milking. In Ethiopia, the deteriorated milk and its product is not safe from consumer health point of view that leads illness to the consumers (Yilma, 2003).Reducing such losses and improving quality are effective ways of making more and safer milk available that benefits both producers and consumers (Felleke, 2003).

Microbial Quality of Milk and Milk Products

Fresh Milk

Fresh milk contains microorganisms that undergo multiplicationwhen improperly handled. Most of microorganisms in fresh milk of healthy animals are either harmless or beneficial but rapid changes in health of an animal or milk handler or contamination from polluted water, dirty, manure, air, cuts and wound make deterioration of raw milk and it becomes potentially dangerous (Othman *et al*., 2008). Health of the animal, cleanliness of the housing area, the nature of feed, the water used at farm, the milk vessels / utensils for storage and essentially the hygiene of the milker / handler are major factors that increase microbial deterioration of raw milk (Chatterjee *et al*., 2006, Ali and Abdelgadir, 2011, and Salman and Hamad, 2011). Harmful pathogens is found in raw milk and the presence of this pathogensis influenced through poor animal husbandry, washing equipment, udder and hands with unsafe water, storing and transportation in unhygienic condition and abuse of storage temperature by milk producers, vendors and shop outlets (Abrahamsen *et al*., 2007). Bacterial pathogens cause food borne diseases due to the consumption of raw milk. This includes Escherichia *coli, Listeria monocytogenes, Salmonella, Campylobacter, Brucella abortus, Staphylococcus aureus, Bacillus cereus, Mycobacterium spp.* and *Clostridium botulinum* (Chye *et al*., 2004). The presence of these pathogens in raw milk is a major public health concern, especially for those individuals who drink raw milk frequently.The prevalence of high population of bacteria in aseptically drawn milk or detection of presence of harmful pathogenic microorganisms is an evidence of unhygienic milk production conditions. Milk contamination by zoonotic pathogens is often natural but can occur through handling milk in unhygienic conditions (Ali, 2010). Lubote, *et al*., (2014) reported that 65% of consumers were not aware that *Salmonell*a and *E. coli* can be transmitted from animals to humans through drinking raw milk and 35% of milk producers were unaware of the zoonotic potential of the most common bacterial contaminants in milk.

Total Bacterial Count

The microbial content of milk is a major feature in determining its quality. Milk from a healthy cow contains few bacteria. It picks many bacteria from the time it leaves the teat of the cow until consumption or further processing. These micro-organisms are indicators of both the manner of handling milk from milking till consumption and the quality of the milk. Milk produced under hygienic conditions from healthy animals should not contain more than 5×10^5 bacteria per milliliter. Different researchers recover total bacterial isolates from fresh milk in their study. Debela (2015) reported that, the total bacterial count obtained from raw milk collected from Yabello District of Borena zone is generally high compared to the acceptable level of 1×10^5 bacteria per ml of raw milk (O'Connor 1994). His study also show that the total bacterial count obtained from market was significantly higher ($P < 0.05$) than milk samples collected from household milk producers which might be due to further contamination of the milk during transportation, use of poorly cleaned milk containers polled and even absence of cooling systems at milk selling points. The total bacterial count obtained from dairy cooperative milk collection centers was significantly higher ($P < 0.05$) than milk samples collected from hotels, small shops/kiosks and small scale milk producers which might be due to further contamination of the milk during transportation, use of poorly cleaned milk containers and absence of cooling systems at milk selling points (Debela, 2015). The author also reported that lack of knowledge about clean milk production contributed to the poor hygienic quality of milk produced in the study area. Gemechu *et al.,* (2014) reported that higher total bacterial count was recovered from milk samples collected from small scale milk producers which could be attributed to improper cleaning of the udder and milking containers before and after milking, failure to use separate towel for each cow, improper cooling system and milk contamination from the hands of producers. The author also reported, using plastic buckets for milk collection and keeping raw milk at room temperature until

sold out in vends shops/kiosks, hotels, dairy cooperative milk collection centers and household of milk producers may lead to high number of total bacterial count in study area. Tassew and Seifu (2010) reported that the overall mean total bacterial count of raw milk collected from farmers and dairy cooperatives was 7.58 log cfu/ml which is high as compared to the acceptable level of 1 x 10^5 bacteria per ml of raw milk.

Coliform Count

Coliforms are other bacterial group which causes milk deterioration which is associated with the level of hygiene during and subsequent handling (Bereda *et al*., 2014). Different study done in Ethiopia show that, coliforms were recovered from raw milks and the count range between 4.03 log cfu/ml and 6.57 log cfu/ml (Tassew and Eyasu, 2010, Yilma and Faye, 2006 and Bereda *et al.*, 2012) of which higher counts of different species of Enterobacteriaceae reported with *E. coli* being the most abundantly isolated species (Yilma *et al*., 2007). Similarly, Debela (2015) recovered coliform from his milk sample collected from market and house hold milk producers and count isolated from milk sample obtained from market was significantly higher ($P < 0.05$) than milk samples obtained from household milk producers with the mean of 6.455 ± 0.030 and 6.192 ± 0.027 log10 cfu/ml, respectively which exceeds European Union standards for coliform counts of raw milk that should be less than 10^2 cfu/ml. The author cited that, the greater coliform count from market milk sample might be due to further contamination of the milk during transportation, inadequately cleaned milking utensils, the practice of washing the milk containers together with other materials and absence or improper cooling systems at milk selling areas. According to Debela (2015), coliform count of milk directly collected from udder, from storage containers at farm level and distribution containers upon arrival at selling point is different and the count was 2.47, 4.93 and 6.52 log10 cfu ml-1 respectively. This show that the coliform count progressively increased by 2.46 log10 cfu ml-1 (99.6%) for milk samples taken from production to arrival at selling point and by 1.59 log10 cfu ml-1 (32.3%) between sampling from milk storage containers at the farm level to sampling from distribution containers upon arrival at selling points.

Factors leading fresh milk contamination with microorganisms in Ethiopia

Barn hygiene

Maintaining the sanitary condition of barn is important for the production of good quality milk. That is clean, dry and comfortable bedding condition minimizes the growth of pathogenic microorganisms. Proper and clean housing environment is a prerequisite to produce milk and milk products of acceptable quality (Tassew, 2007). Debala (2015) reported that, the farmers in Yabello district of Borena zone do not use bedding material for their animals and 56.7% of them clean the barn once a week, while 38.9% clean more than once a week. 4.4% of them reported to clean once a month. Practices that expose the teat end to organic bedding sources, wet and muddy pens increase the risk of occurrence of mastitis and milk contamination (Ruegg, 2006).

Hygienic condition during milk production

Hygienic production of milk is important for the safety of consumers. The hygienic conditions are different according to the production system, adapted practices, level of awareness, and availability of resources. In under small holder 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), is not secured adapted practices (Yilma, 2003).

FSA (2006) indicated that cleaning of the udder before milking is important to remove both visible dirt and bacteria from the outer surface of the udder. Getachew (2003) also indicated milk producers should follow hygienic practices (clean utensils, washing milker's hands, washing the udder, use of individual towels) during milking and handling, before delivery to consumers or processors. Besides udder infection and water quality, hygienic behavior with respect to hand washing, containers cleaning and disinfection are the key areas that need hygiene intervention (Bonfoh *et al*., 2006).

In Ethiopia, there is no standard hygienic condition followed by producers during milk production. Milk can be contaminated by microorganisms at any point from production to consumption. According to Debala (2015) report on the study done on quality of milk in Yabello district, the majority of farmers (87.8%) do not get training previously on milk handling system, milk utilization, preservation and marketing. Welearegay *et al*. (2012) reported that most dairy farm owner's in his study conducted in Hawassa cleaned their cows udder with warm water but they did not perform the cleaning sufficiently and do not dry it property. According to his study, about 60, 28 and 8.3% of the producers respectively used warm water, cold water and both warm and cold water alternatively for cleaning udder of, but the water sources used for cleaning in all farm categories were tap water (63.6%) followed by borehole water (30.5%) and lake and river water (5.8%). However, when water from non-tap sources is used for cleaning purpose; it is important that producers should at least filter and heat before using because the quality of water determines the amount of bacterial counts (Yilma, 2009). The other sanitary procedure after washing the teat is cleaning with clean dry cloth or towel to dry the udder of the cow. According to Welearegay, 48% of milk producers in all farm size groups do not use towel to dry udder after washing rather they massage the udder with bare hands; while about 44% of them reported to use common towel. About 4.6% farmers reported that they do not practice udder washing and drying.

Hygienic condition of milking and storage equipments

The equipment used for milking, transportation and storage determine the quality of milk and milk products. Of this, types of milk containers especially during transportations of milk to the selling point greatly determine the qualities of milk. Milk storage and transportation are aimed at having good quality milk available where and when needed for processing (Walstra*et al*., 1999). Producers need to pay attention for the

type as well as cleanliness of milk equipment (Debala, 2015). There are washing practices of milk handling equipment with plants and smoking of milk handling containers. Welearegay *et al*. (2012) reported that all farmers (85.6%) use warm water together with detergents to wash milk handling equipment while 12.1% of them cleaned with cold water. About 43.2% of the producers used different plants (Eucalyptus globules, Ocimum hardiense, Ruta chalepensis, Cymbopogan martini and Agave sisalena) to fumigate before and after use of milk and milk products.

Hygienic condition during marketing

Degree of cleanliness of milking equipments depends on the procedure which is adopted for cleaning and sanitizing. According to Debala (2015) report, majority of households in the study area were practicing washing and smoking of the milking utensils regularly before and after milking. His survey indicate that, 78% of milk producers use unboiled water to wash equipment, udder and hands while 89% of them did not use detergents/disinfectants. About 79% of them did not have milk storage facilities and 82% were not practicing good animal husbandry. Furthermore, 69% of vendors and 66% of milk shops had no good storage facilities. Similarly Gemechu *et al*., (2014) reported that, all the households he surveyed milk their cows by using hand milking either washing cow teats or letting calf to suckle its dam for minutes to stimulate milk let-down. About 71.79% of milk producers milk their cows using hand milking by washing teats without calf suckling while 28.21% of milk producers milk their cows by hand after calf suckling.

Microbial quality of milk products

Cheese

Cheese is a fresh or matured product obtained by draining after coagulation of the whole, skimmed or partially skimmed milk. Its principle of processing is based on the coagulation of the protein in milk, during which about 90% of the milk fat is encapsulated. The coagulated mass is called curd; the remaining liquid is called whey. Curd consists mainly of milk proteins (casein) and milk fat; while whey mainly contains water, milk sugar (lactose), protein (serum proteins) and B-vitamins (Pauline, 2006).

Cheese can be considered as a good medium for bacterial growth due to their nutrient content and long storage duration. Several steps in their production can cause bacteriological hazards. Though pasteurization of milk can destroy most of the pathogens posing risk to public health, yet, the potential bacteriological hazards can still be found in the final products after pasteurization through the improper handling. The results indicate the unhygienic conditions prevailing during distribution or sale where most of the products are sold in open containers at local market (Senbetu, 2014).

Yogurt

Yoghurt is a diaryproduct produced by thecontrolled fermentation of milk by lactic acid producing bacteria. Two species are commonly used in thecommercial production, which are *Lactobacillus bulgaricus* and *Streptococcus thermophiles* (*Makut et al.,* 2014). *Ergo* is a traditional Ethiopian fermented milk product, which has some resemblance to yoghurt. It has thick, smooth and uniform appearance. It has white milky color when prepared carefully. It constitutes a primary sour milk product from which other products may be processed (Almaz *et al.*, 2001). As the major fermented dairy product, *Ergo* is popular and is consumed in all parts of the country.

Worku *et al*. (2015) reported on the study done on commercially prepared and traditionally Homemade Yoghurt (Ergo) retailed in Addis Ababa, the average count of LAB was found to be log 9.6 cfu/ml; and that of aerobic mesophilic bacteria (AMB) and psychrophilic bacteria (PB) was shown to be around log 9 cfu/ml. Similarly the average count of coliform and fecal coliforms were indicated to be around log 6 cfu/ml.

Butter

Butter is a traditional food which is widely consumed all over the world, directly or as ingredient in processed food such as pastries and convenience dishes. Its nutritional value (due to high content of fats, vitamins and minerals), and unique and pleasant flavour make butter practically appreciated by consumers. Butter can be made directly from milk or by separation of milk and subsequent churning of the cream (Kacem and Karam, 2006), but Ethiopian traditional butter (Kibe) is made from Yoghurt (traditional Ergo) not from cream (Bereda, 2014). Butter has an attractive appearance with white to yellowish color and semi-solid at room temperature. It has pleasant taste and odor when fresh but, changes in taste and odor occur if it is not stored in unrefrigerated condition and not further processed. Butter is the most shelf stable of milk products and it has important role in diet, both in rural and urban areas. In addition to direct consumption, butter is used as oil for food preparation and in Ethiopia it is also used for hair dressing and as skin cosmetics by both sexes and for coffee roasting in traditional ceremonies (Yonad, 2009). The moisture content of traditional Ethiopian butter ranges from 20 to 40% compared to international standard butter of 16%. Butter spoilage occurs by putrefying microorganisms when it is stored in unrefrigerated condition for long period of time. Microorganisms having lipolytic activity highly cause the rancidity or loss of flavor of butter. Yilma (2010) reported that the average total bacterial count of 6.18cfu/g and 7.25cfu/g was isolated from butter sample collected from Selale and Sululta respectively. Similarly Wondu (2007) reported the average TBC of 7.49 cfu/g in which higher count was recovered from butter samples collected from rural producers and open markets compared to sample collected from dairy farms.

Conclusion

Milk and milk products are the perfect and food of high biological value which consumed in urban and rural areas of Ethiopia. However, the microbial quality of Ethiopian milk and milk products is not to the standard and subjected to post-harvest and pre-consumption spoilage which result in milk borne illness. This is due to absence of standard production and processing conditions. Majority of Ethiopian dairy farm is

practiced in rural and in small scale conditions. Milk marketing system is not well developed and for the majority of small scale producer's access to market is limited. This and other with milk mishandling, contamination during milking, less quality long storage at high ambient temperature before consumption; inefficient transportation and distribution systems; inefficient and less quality processing technologies contribute to the spoilage of milk and milk products. In general unhygienic cleaning and handling of milk and milk product, product equipments, less hygienic knowledge of producers which is more of traditional way of production and inefficient and inadequate dairy technology affect the microbial quality of Ethiopian milk and milk products. Therefore, awareness on hygienic production and handling of milk and products should be given to farmers, hygienic control measure from production to consumption should done and adequate production and processing technologies should be fulfilled.

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