

Review

Microbiological Quality Assessment of Raw and Pasteurized Milk

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Accepted 04 June, 2015

Milk has an outstanding nutritional quality but it is also an excellent medium for bacterial growth and an important source of bacterial infection when consumed without pasteurization. Microbial contamination might generally occur from within the udder, exterior to the udder and from the surface of milk handling and storage equipment. Raw milk collection and its transportation to the processing centers present a number of technical, economical and organizational problems in most developing countries. Hygienic quality control of raw milk and milk products in Ethiopia is not usually conducted on routine basis. Some of the disease causing bacteria in the milk are *Salmonella spp.*, *M. bovis*, *Corynebacterium spp.*, *C. perfringens*, *Yersinia enterocolitica*, *Coxiella burnetii*, *Brucella*, *Staphylococcus spp.*, *Campylobacter jejuni*, *M. avium*, *Listeria spp.*, *E. coli*, and other coliforms. Many bacteria could get an easy access to milk and milk products such as *E. coli*, coliform and they are often used as indicator organisms to confirm the bacterial contamination of milk. The higher total bacterial counts and isolation rates of some public health important pathogens were observed in these literatures conducted in different study areas of the country and the consumption of raw/unpasteurized milk carries an important public health risk.

Key words: Raw milk, pasteurized milk, microbiological quality assessment, coliforms.

INTRODUCTION

Milk is the lacteal secretion of the mammary glands of a mammal. It is the first natural food of all young mammals during the period immediately after birth (Gebra-Emanuel, Teka, 1997). Milk is a compensatory part of daily diet especially for the expectant mothers as well as growing children. Because of its nutritive value, milk is considered as one of the most important diet items of many people (Mehari, 1998). Nutritionally, milk has been defined as "the most nearly perfect food" and it is an outstanding source of calcium and phosphorus for bones and teeth, and contains vitamin B6, A and B1 in significant amounts (O'Mahony, 1988).

The demand of consumers for safe and high quality milk has placed a significant responsibility on dairy producers, retailers and manufacturers to produce and market safe milk and milk products (Mennane *et al.*, 2007). Milk and milk products have important role in feeding the rural and urban population of Ethiopia owing to its high nutritional value. It is produced daily, sold for cash or readily pro-

cessed. It is a cash crop in the milkshed areas that enables families to buy other food stuffs and significantly contributing to the household food security (Abebe *et al.*, 2012).

Milk is virtually a sterile fluid when secreted into alveoli of udder. However, beyond this stage of production, microbial contamination might generally occur within the udder, exterior to the udder and from the surface of milk handling and storage equipments, but the surrounding air, feed, soil, feces and grass are also possible sources of contamination (Solomon *et al.*, 2013).

Raw or processed milk is a well-known good growth medium that supports the growth of several microorganisms because of its high water content, nearly neutral pH, and variety of available essential nutrients that renders it as one of the good media for microbial growth and multiplication (Soomro *et al.*, 2002; Teka, 1997). The bacterial contamination of milk not only reduces the nutritional quality but also consumption of such milk threatens health of the society (Fadaei, 2014). Microorganisms may contaminate milk at various stages of procurement, processing and distribution. The ill health of the cow and its environment, improperly cleaned and sanitized milk handling equipment, and unhygienic workers who milk the cow could serve as sources of contamination.

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Lack of refrigeration facilities at farm and household level in developing countries of tropical regions, with high ambient temperature implies that raw milk will easily be spoiled during storage and transportation (Gilmour, 1999; Godefay and Molla, 2000).

Although milk is known to possess several anti-microbial agents, bacterial number will be doubled in less than 3hrs in unchilled milk. The rate of microbial growth will depend on initial numbers and the temperature at which milk is held immediately after milking and thereafter (Kurwijilla *et al.*, 1992). Milking equipment, utensils, and storage tanks are the major source for psychrotropic contamination of raw milk (Suhren, 1989) cited by (Desalegn, 2014).

Preventing products defect that result from the growth of psychrotrophic bacteria in raw milk involves limiting contamination levels, rapid cooling immediately after milking and maintenance of cold storage temperatures (Frank and Koffi, 1990). Milk and milk products may carry toxic metabolites of different organisms growing in it. Ingestion of such products, contaminated with these metabolites, cause food poisoning (Aneja *et al.*, 2002).

Defects in fluid milk caused by coliforms and lactic acid bacteria are controlled by good sanitation practices, pasteurization and refrigeration of pasteurized products (Doyle. *et al.*, 2001). Food-borne diseases are caused by a wide range of agents and can result in mild indispositions or life threatening illnesses. The true scale of their impact on health remains unknown since only a small proportion of cases come to the notice of health services and even fewer are investigated. In many developing countries reliable quantitative data is large lacking (WHO, 1992).

Different studies have been conducted in Ethiopia to evaluate the microbial quality and hygienic milking practices in processing plants and smallholder dairy farms in different part of the country with variable results a few of which include (Alehegne, 2004; Lumadede *et al.*, 2010; Desalegn, 2014; Asaminewand Eyassu, 2011; Solomon *et al.*, 2013; Abebe *et al.*, 2012; Zelalem, 2012; Aberra, 2010; Haile, 2012; Dehinet *et al.*, 2013). The above researches result reveals that the microbial quality (load) of raw and pasteurized milk collected from different sampling point (market chain) were poor as compared with the established standard of raw milk quality in Ethiopia.

Hygienic control of milk and milk products in Ethiopia is not usually conducted on routine bases. Apart from this, door-to-door raw milk delivery in the urban and peri-urban areas is commonly practiced with virtually no quality control at all levels (Godefay and Molla, 2000). The safety of dairy products with respect to food-borne diseases is a great concern around the world. This is especially true in

Miscellaneous Sources of Bacteria in Raw Milk

Although the air of the milking environment rarely contributes a significant number of the total microbial count of milk, extremely dusty conditions may increase the counts. Milk

developing countries where production of milk and various milk products takes place under unsanitary conditions and poor milk production practices (Mogessie, 1990). Therefore, provision of milk and milk products of good hygienic quality is desirable from consumer health point of view (Zelalem, 2012).

In general in order to make milk free from bacterial pathogenic agents, Hazard Analysis and Critical Control Point system should be done starting from milk collection through milk processing to milk storage (FAO/WHO 1997).

Milk Marketing

Informal milk marketing accounts for over 70% of total milk sales in Addis Ababa and accounts for the majority of urban dairy farm milk production. Raw milk is marketed locally by smallholder urban producers directly or through middlemen. Raw milk is generally produced in very unhygienic conditions; it is after adulterated, and can transmit zoonotic diseases which present a public health risk. Formal milk marketing of pasteurized milk and milk products accounts for fewer than 30% of total milk sales in Addis Ababa even though these products are hygienically prepared and considered safe for human consumption (UDSS, 2006).

Bacteriological Quality of Raw Milk

Milk 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). Because of the specific production it is impossible to avoid contamination of milk with microorganisms therefore the microbial content of milk is a major feature in determining its quality (Karmen and Slavica, 2008). Presence and multiplication of saprophytic bacteria in raw milk might change the milk composition and influence the quality of the product (Godefay and Molla, 2000). Organisms unable to grow at refrigeration temperatures remain at low numbers, implying that temperature is an important factor contributing to the prevalence and proliferation of specific organisms in the milk (Karmen and Slavica, 2008). Bacterial contamination of raw milk can originate from different sources: air, milking equipment, feed, soil, faeces and grass. The number and types of microorganisms in milk immediately after milking are affected by factors such as animal and equipment cleanliness, season, feed and animal health. It is hypothesized that differences in feeding and housing strategies of cows may influence the microbial quality of milk (Coorevits *et al.*, 2008). Rinsing water for milking machine and milking equipment washing also involve some of the reasons for the presence of a higher number of microorganisms including pathogens in raw milk (Karmen and Slavica, 2008).

handling personnel (milker, butter maker, cheese maker, etc.) may contribute various organisms including pathogens especially when they are careless, uninformed, or willfully negligent, directly to milk (Ashenafi and Beyene, 1994). The soils, while the cows are in pasture, manure, the animal coats, tails etc. are

Table 1. Grade of raw milk based on standard plate count (SPC).

Bacterial count/ml	Grade
Not exceeding 200,000	Very good
200,000 -1,000,000	Good
1,000,000-5,000,000	Fair
>5,000,000	Poor

Source: Kurwijilla *et al.*, (1991).

some of the possible sources of contamination of milk (Teka, 1997). Mastitis, external udder surfaces, inadequate cooling of the milk, improper udder preparation methods, unclean milking equipment and the water used for cleaning purposes are considered as the main source of milk contamination (Dehinenet *et al.*, 2013).

Coliform Bacteria in Raw Milk

Coliforms are group of bacteria, which inhabit the intestinal tracts of human and animals. They are excreted in large number with human excreta and animal droppings. They may be found in the soil, on vegetables and untreated water (Gebra-Emanuel, Teka, 1997). It includes all aerobic and facultative anaerobic, gram-negative, none spore forming rods able to ferment lactose with the production of acid and gas at 35°C within 48hrs. Most of them belong to the genera *E. coli*, *Enterobacter* and *Klebsiella* (Godefay and Molla, 2000).

Coliform organisms contaminate raw milk from unclean milker's hands, improperly cleaned and unsanitized or faulty sterilization of raw milk utensils especially churns, milking machines, improper preparation of the cow's flecks or dirt, manure, hair dropping in to milk during milking, udder washed with unclean water, dirty towels and udder not dried before milking (Desalegn, 2014). The presence of coliform organisms in milk indicates unsanitary conditions of production, processing or storage. "Hence their presence in large number in dairy products is an indication that the products are potentially hazardous to the consumers' health (Godefay and Molla, 2000).

The disease causing bacteria in the milk are *Salmonella spp.*, *Mycobacterium bovis*, *Corynebacterium spp.*, *Clostridium perfringens*, *Yersinia enterocolitica*, *Coxiellaburnetii*, *Brucella*, *Staphylococcus*, *Campylobacter jejuni*, *Mycobacterium avium*, *Listeria spp.*, *E. coli*, and *coliforms* (Lumadede *et al.*, 2010; Asaminewand Eyassu, 2011; Solomon *et al.*, 2013; Abebe *et al.*, 2012; Zelalem, 2012; Aberra, 2010; Haile, 2012; Dehinenet *et al.*, 2013). Most common pathogens that have been involved in milk borne diseases include *Salmonella spp.*, *Staphylococcus aureus*, and *E. coli* (Fadaei, 2014).

In recent years, there are several studies related to raw milk contamination including: infection with *C. jejuni*, *Listeria monocytogenes*, and *E. coli* strain O157 (Vahediet *et al.*, 2013), *Campylobacter spp.*, *Salmonella spp.* and *E. coli* (Griffiths, 2010), *C. jejuni*, *E. coli*, *coliforms*, *S. aureus* (Vahedi *et al.*, 2013). The quality and safety of raw milk can be evaluated by assessing hygiene indicator microorganisms. Total coliform, *E. coli* and *S. aureus* are used as hygienic parameters for milk production, as they indicate the conditions of raw milk obtaining and storage, and inadequate handling during the manufacturing process. The presence of these pathogenic bacteria in milk appeared as main public health concerns, especially for those people who still drink raw milk (Fadaei, 2014).

Public Health Importance of Raw Milk and Milk Products

Milk, either raw or processed, is a well-known vehicle for a number of human pathogens. Milk and milk products have, therefore, pose a health risk to consumers if it is contaminated by any pathogens and subjected to temperature abuse where these organisms can multiply to high counts and may produce toxins. In countries where food borne illness are investigated and documented, the relative importance of pathogens like *S. aureus*, *E. coli*, *salmonella spp.* and *listeria spp.* is well known (Godefay and Molla, 2000). As different literatures reveal that *Mycobacterium bovis*, *Mycobacterium tuberculosis*, *Salmonella spp.*, *Brucella spp.*, *Brucella spp.*, *Listeria monocytogenes*, *Staphylococcus aureus*, *Campylobacter jejuni*, *Yersinia enterocolitica*, *Escherichia coli*, *Yersinia enterocolitica*, *Streptococcus agalactiae*, *Corynebacterium ulcerans* are some of the most important disease causing microorganisms that can be found in milk (Sinha, 1994a; Sinha, 1994b; Vlaemynck, 1994; Garin-Bastuji *et al.*, 1994; Soomro *et al.*, 2002; Prentice, 1994; Asperger, 1994; Teka, 1997).

Public Health Standards of Raw and Processed Milk

The public health standard for milk ordinance provides chemical, bacterial and temperature standards as well as

sanitation requirements for production and processing of raw and pasteurized milk and milk products. Some processors may often be motivated by incentives for producers to meet more stringent standards to improve milk quality (Hagstad and Hubbert, 1986).

High initial microbial count in milk $>10^5$ cfu/ml in evidence of serious faults in milk production hygiene, whereas production of milk having counts consistently $<10^5$ cfu/ml reflects good hygiene practices (Ombui *et al.*, 1995). A standard plate count of 1×10^5 cfu/ml has been widely adopted for good quality raw milk intended for treatment before liquid consumption. However, some other countries have adopted different standards suited to local conditions. For example, the standard plate count for America is no more than 3×10^5 cfu/ml, while the standard for Kenya is no more than 2×10^6 cfu/ml (Ombui *et al.*, 1995). In Sweden the accepted limit for the total number of bacteria and somatic cell count in raw milk is 1×10^5 cfu/ml and 4.99×10^3 somatic cells/ml respectively (Alehegne, 2004). The standard plate count for pasteurized milk should be less than 3×10^4 cfu/ml (Saskatchewan, 1997). Coliform counts regularly in excess of 150 cfu/ml are considered generally as evidence of unsatisfactory production hygiene. However, relatively low coliform counts in milk don't necessarily indicate effectively cleaned and disinfected equipment (Alehegne, 2004).

Pasteurization

Pasteurization is the process of heating milk for a predetermined time at a predetermined temperature to destroy pathogens. The thermal destruction process is logarithmic, and bacteria are killed at a rate that is proportional to the number of bacteria present. Pasteurization improves the safety and lengthens the shelf life of a product by destroying pathogenic and spoilage organisms (Jeffrey *et al.*, 2009). It was named after Louis Pasteur who discovered that spoilage organisms could be inactivated in wine by applying heat at temperatures below its boiling points. The process was later applied to milk and remains the most important operation in the processing of milk (Namminga, 1999).

Pasteurization destroys most disease producing organisms and limits fermentation in milk, beer, and other liquids by partial or complete sterilization. The pasteurization process heats milk to 72°C for 15 seconds, inactivating or killing organisms that grow rapidly in milk. Pasteurization does not destroy organisms that grow slowly or produce spores. While pasteurization destroys many microorganisms in milk, improper handling after pasteurization can re-contaminate milk (UDSS, 2006). Basically there are two distinct purposes for the process of milk pasteurization; i) Public health aspect-to make milk and milk products safe for human consumption by destroying all bacteria that may be harmful to health. ii)

Keeping quality aspects-to improve the keeping quality of milk and milk products (Clarence, 1990).

CONCLUSION AND RECOMMENDATION

Regardless of having a significance difference among the studies conducted in different processing plants and smallholder dairy farms in different parts of the country, total bacterial count (TBC), total coliform count (TCC), Fecal coliform count (FCC) and detections of significant public health important pathogenic bacteria results illustrated that the quality of milk in the study of processing plants and smallholder dairy farms were poor as compared with the established standard of raw milk quality in Ethiopia. The higher coliform and total bacterial counts observed in these literatures conducted in different study areas of the country could be due to contamination of raw milk samples either from the cows, the milker, milk container and the milking environment and transportation utensils. Therefore, sanitary measures should be installed at all stages starting from production to consumption, the state regulatory agency shall set a hygienic standard bases on the local condition and routinely control the quality of milk produced by such urban and peri-urban producers, and introducing different dairy technologies should be supported with a continuous training on how to manage dairy farms to discourage adulteration, since milk is a known vehicle for a number of human pathogenic microbes.

ACKNOWLEDGEMENT

The authors are thankful to the Dean, Dr. Ayalew Niguse, College of Veterinary Medicine Jigjiga University, Jigjiga, Ethiopia for his support and cooperation.

Competing Interests

The authors declare that they have no competing interests.

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