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Microbiological Quality of Raw Camel Milk in Degahbour District of Jarar Zone, Somali Regional State, Ethiopia

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Abstract

A cross-sectional study was carried out to evaluate microbiological quality of raw camel milk in Degahbour district. A total of 40 pooled raw camel milk samples (each with a volume of 450 mL) were collected from the udders and milk handling equipment of producers in Degahbour district. The raw milk samples were subjected to laboratory analyses to evaluate standard plate counts (SPC), total coliform count (TCC) yeast and mold count (YMC) to determine the microbiological quality of the raw camel milk in the study area. The overall mean SPC, CC and YMC for raw camel milk samples collected from the udder was 5.35 ± 0.19, 2.59 ± 0.16 and 1.71 ± 0.12, respectively. The overall mean counts for samples collected from the equipment of producers were 6.72 ± 0.17, 4.71 ± 0.23 and 1.61 ± 0.21 for SPC, CC and YMC, respectively. Significant difference ($P < 0.05$) in mean SPC, TCC and YMC was observed between milk samples collected from pastoral and agro-pastoral production systems as well as collected from udders and milk equipment. In general, it was concluded that raw camel milk samples collected from the udder as well as from the equipment of producers were contaminated with SPC, CC and YMC, with loads exceeding the respective acceptable limits. Therefore, hygienic production and postharvest handling practices need to be followed to improve the quality and suitability of camel milk for its intended use in the study area.

Keywords

Microbiological Quality, Production System, Raw Camel

1. Introduction

Camel milk, so called white gold of the desert, is more similar to human than

any other milk and differs from other ruminant milk because it contains low cholesterol, low sugar, high minerals (sodium, potassium, iron, copper, zinc and magnesium), high vitamin C (three times more than cow milk) [1]. Camel milk is a valuable food source for humans in the arid and semi-arid environment of eastern Africa [2]; particularly, it is a primary source of food, nutritional and income security all year round for some pastoralists in the region [3]. Furthermore, camel milk enhances livelihoods and contributes to national and global economic growth and development [4]. Camel milk is also used as a traditional medicine to treat several diseases, and as a result, it builds the immune system of human beings when consumed occasionally [5] [6]. Therefore, camel milk is at the core of some pastoralists' culture, life and health and is considered as white gold of the desert [7].

Although camel milk has a very good nutritional and medicinal value, it is an excellent growth medium for a wide range of spoilage and pathogenic microorganisms [8]. The risk of camel milk contamination with harmful microorganisms is high for milk produced in developing countries like Ethiopia as milk production practices in such countries is traditional type which lack appropriate hygienic measures [9], and cause spoilage loss of milk. The risk is very high for milk produced in lowland regions. This is mainly due to high ambient temperatures prevalent in the area combined with lack of cooling facilities, scattered distribution of producers, long distance to markets and lack of transportation [10]. On Other hand, camel milk is mainly consumed in its raw form without being subject to any sort of treatment by pastoral societies in developing countries [11] Like in other developing countries pastoralist and agro-pastoralist in Ethiopia including in the study area consume camel milk in its raw form. This is because it is believed that raw camel milk and its byproducts have nutritional and medicinal advantages as well as better flavor over the pasteurized milk. However, such practices may expose consumers to serious milk-borne health risks like typhoid, paratyphoid, tuberculosis, dysentery, gastrointestinal illness and others [12]. The potential risk is high for consumers (especially growing children and immuno-compromised persons) feeding on milk produced under traditional systems which lack appropriate hygienic control and marketed through informal channels [13].

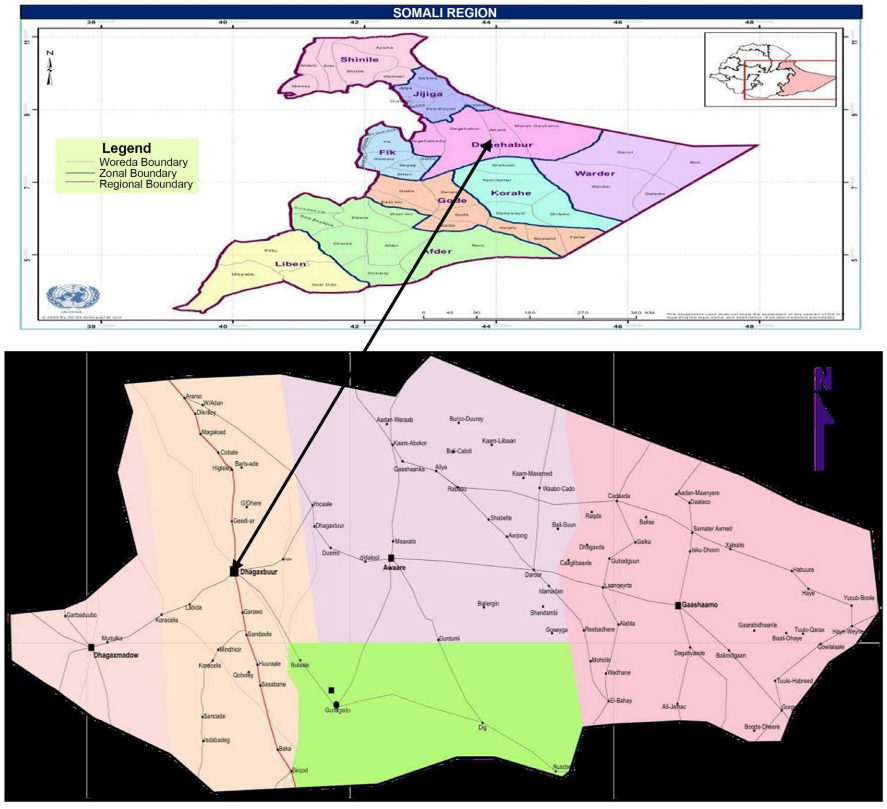
The availability of documented information on the microbiological quality of raw camel milk is highly important. This is because such information may be important for governmental, nongovernmental and other developmental organizations to be focused on it, and undertake relevant development interventions, which make milk producers to have clear understanding on the hygienic practices essential for safe milk production and handling. This understanding may be important to ensure safety and suitability of raw camel milk for its intended use. However, currently there is no well documented information available on the microbiological quality of raw camel milk in the study area where camel milk is highly consumed in its raw form as well as marketed through informal marketing channels. Therefore, the present study was designed to evaluate microbio-

logical quality of raw camel's milk in Degahbour district of Jarar zone, Somali Region, Ethiopia.

2. Materials and Methods

2.1. Study Area

The study was conducted in Jarar Administrative Zone of Somali Regional State, specifically in Degahbour district. The district is located at 8˚13'N latitude and 43˚34'E longitude at 777 km east of Addis Ababa. The altitude of the district ranges from 1044 meters above sea level (m.a.s.l.). It has mean annual minimum and maximum temperature of 5˚C and 38.5˚C, respectively. The mean annual rainfall the area ranges from 300 - 400 mm. The two prevailing agricultural production systems in the district are pastoral and agro-pastoral production systems [14]. According to CSA [15], the district has a total population of 115,555; out which about 65,081 and 50,474 are men and women, respectively. Of the total human population of the district, about 74.015% and 25.98% are rural and urban dwellers, respectively. The average family size for rural and urban areas is 6.7 and 6.8 persons, respectively.



2.2. Study Design

A cross-sectional study was conducted from February 2019 to January 2020 to determine the microbiological quality raw camel milk in Degahbour district. Pooled raw cowmilk samples were taken repeatedly from udders of lactating ca-

mel as well as from milk handling equipment of producers, and subjected to laboratory analysis. The laboratory analysis was done in Jigjiga University microbiology laboratory, Ethiopia.

2.3. Sampling Targets

Degahbur district was selected for this study due to its potential of camel milk production. The district was stratified into pastoral and agro-pastoral production systems. Each production system was further stratified into kebeles. Thus, a total of four kebeles (2 from pastoral and 2 from agro-pastoral production systems) with high camel milk production potential were purposively selected for this study. The lists of camel milk producer households were taken from their respective administration. Eventually, 30 milk producer households from each rural kebele (RK) were selected randomly, and were considered for sampling of raw camel milk.

2.4. Milk Sample Collection

For the evaluation of microbiological quality of raw camel milk, a total of 40 pooled raw camel milk samples (each with a volume of 450 ml) were collected from the udder (n = 20; 5 from each kebele) and milk handling equipment of producers (n = 20; 5 from each kebele) following the sampling stratification described above (under Section 2.3). The samples were placed in an icebox (≤4˚C) to restrict microbial multiplication and were transported to Jigjiga University microbiology laboratory. Upon arrival at the laboratory, the samples were kept in refrigerator (having temperature between 0˚C - 4˚C) until the time of analysis. The analysis was carried out within 24 hours period after collection.

2.5. Microbiological Analysis

2.5.1. Standard Plate Count

Standard plate count was determined using standard plate count agar. One mL of raw milk sample was added into a sterile test tube containing 9 ml of sterile peptone water. After thoroughly mixing, the suspension was serially diluted up to 10^{-11} and duplicate samples from the appropriate dilution (1 ml) was pour-plated using a 15 - 20 ml of cooled but still molten standard plate count agar solution and mixed thoroughly. The resulting plates were allowed to solidify and then incubated at 32˚C for 48 hours [16]. The plates with colonies ranging from 30 to 300 colony forming units (cfu) mL^{-1} were selected for determination of standard plate count [16]. Standard plate count was determined as the total number of cfu per milliliter of milk sample was calculated using the formula provided by FDA [17].

$$N = \frac{\sum C}{\left[\left(1\times n1\right)+\left(0.1\times n2\right)\right]d}$$

where, N = Number of colonies per ml of milk sample

$\sum C$ = Sum of all colonies on plates counted

$n1$ = Number of plates used in lowest dilution counted
$n2$ = Number of plates used in highest dilution counted
d = dilution factor of the lowest dilution used.

2.5.2. Total Coliform Count

TCC was determined using sterile violet red bile agar (VRBA). One ml of raw milk sample was added into a sterile test tube containing 9 ml of sterile peptone water. After thoroughly mixing, the suspension was serially diluted up to 10^{-9} and duplicate samples (1 ml) were pour-plated using a sterile 15 - 20 ml VRBA. After thoroughly mixing, the resulting plates were allowed to solidify and then incubated at 32˚C for 24 hours [18]. After incubation, typical dark red or purplish-red colonies appearing on the plates were counted as coliforms. For confirmatory test, five to ten typical colonies from each plate will be transferred into tubes containing 2% Brilliant Green Lactose Bile Broth and incubated at 37˚C for 48 hours [16]. Growth and gas production within incubation period was considered as sufficient evidence for the presence of coliforms [16]. Plates with 15 to 150 cfu·ml^{-1} were used [19] for determining total coliform counts using the formula provided by IDF [20].

2.5.3. Yeast and Mould Count

Yeast count (YC) and mold count (MC) were determined using sterile Potato Dextrose Agar (PDA). One ml of raw milk sample was added into a sterile test tube containing 9 ml of sterile peptone water. After thoroughly mixing, the suspension will be serially diluted up to 10^{-7} and duplicate samples of 0.1 ml were spread-plated on pre-dried surfaces of media containing PDA (Oxoid, UK). The plates were then incubated at 25˚C for 5 days [16]. Creamy to white/gray colonies were counted as yeasts whereas, filamentous (fuzzy) colonies of various colors (yellow, green, light brown) will be counted as molds [21] When difficulties were faced to differentiate some colonies whether they are yeast or mold, a microscopic examination using the oil immersion objective was carried out to identify whether the cells in the colonies are unicellular or multi-cellular. Plates with 10 to 150 colonies were used for determining yeast and mold counts using the formula provided by IDF [20].

2.6. Data Analysis

Data collected from laboratory were summarized in Microsoft Excel and SAS (2008 version) was used for descriptive statistical analysis. The SPC, TCC and YMC data expressed in colony forming units per milliliter (cfu·ml^{-1}) were transferred into logarithmic scale (log10) and analyzed using general linear model (GLM) procedure of SAS [22]. Mean comparison used by Tukey's adjustment. The difference was considered significant at the level $P < 0.05$. The following model was used for the analysis:

$$Y_{ijk} = \mu + P_i + M_j + P_i * M_j + E_{ijk},$$

where:

Y_{ijk} = Standard plate count, total coliform count, yeast and mold count,
μ = population mean (overall mean)
P_i = the effect of i^{th} production system (i = 1, 2)
M_j = the effect of j^{th} milk source (j = 1, 2)
$P_i * M_j$ = interaction between production system and milk source
E_{ijk} = random error.

3. Result and Discussion

3.1. Microbial Quality of Camel Milk

3.1.1. Standard Plate Count

Production system had significant ($P < 0.01$) effect on standard plate count (SPC). Thus, the average SPC for raw camel milk samples collected from the udder of milking camels in pastoral production system (5.86 ± 0.18 log10 cfu·ml^{-1}) was significantly higher ($P < 0.001$) than in agro-pastoral production system (4.85 ± 0.20 log10 cfu·ml^{-1}) (Table 1). Moreover, the mean SPC for raw milk samples collected from the storage equipments in pastoral production system (7.47 ± 0.13 log10 cfu·ml^{-1}) was significantly higher ($P < 0.05$) than in agro-pastoral production system (5.41 ± 0.21 log10 cfu·ml^{-1}) (Table 1). Such variation in between pastoral and agro-pastoral production system may be due to the difference in hygienic practices performed during milk production and postharvest handling. Moreover, such difference may be due to the variation in ambient temperature between two production systems. It has been reported that, the temperature of food including milk handling area highly determines the microbial count of food as temperature determines the microbial activities like multiplication of microorganisms in food like milk [23][24].

Table 1. Least square mean (±SE) standard plate count (log10 cfu·ml^{-1}) of raw camel milk samples collected in the study area.

Variables	Standard plate count (SPC)
Production system (n = 40)	***
Pastoral	6.66 ± 0.14^{a}
Agro-pastoral	5.41 ± 0.14^{b}
Milk sources (n = 40)	**
Milk equipment	6.72 ± 0.15^{a}
Udder	5.35 ± 0.15^{b}
Production system * milk sources	*
Pastoral * milk equipment	7.47 ± 0.18^{a}
Agro-pastoral * milk equipment	5.97 ± 0.18^{b}
Pastoral * udder	5.86 ± 0.18^{b}
Agro-pastoral * udder	4.85 ± 0.18^{c}
Overall mean	**6.04 ± 0.17**

n = number of samples taken; significance: *$P < 0.05$, ** $P < 0.01$, ***$P < 0.001$, SE. = Standard error.

Moreover, milk source had significant ($P < 0.01$) effect on SPC of raw camel milk sampled in the study area. Thus, the mean SPC for raw camel milk samples collected from the udder (5.86 ± 0.18 log10 cfu·ml^{-1}) were significantly ($P < 0.001$) lower than that for samples collected from the equipment of producers (7.47 ± 0.13 log10 cfu·ml^{-1}) in pastoral production system (Table 1). Moreover, in agro-pastoral production system, the mean SPC for raw camel milk samples collected from the udder (4.85 ± 0.20 log10 cfu·ml^{-1}) were significantly ($P < 0.001$) lower than samples collected from the equipment of producers (5.97 ± 0.22 log10 cfu·ml^{-1}) (Table 1). This might be due to further contamination of the milk during production and postharvest handling.

The mean SPC of raw milk samples collected from the udder of milking camel in the study area was 5.35 ± 0.19 log10 cfu·ml^{-1} (Table 1). The finding is higher than 4.20 log10 cfu·ml^{-1} reported by Tsegelem *et al.* [25] for milk samples collected from the udder of milking camel in Fafan zone. However, the finding was lower than the value (5.62×10^1 cfu·ml^{-1}) reported for raw camel milk samples collected from the udder of milking camel in Afar zone, Ethiopia [26]. The difference may be due to the difference in hygienic practices (like udder, hand, milking equipment washing and other practices) performed among milk producer households in different location.

The mean SPC of raw milk samples collected from the equipment of producers in the study area was 6.72 log10 cfu·ml^{-1} (Table 1). The finding is higher than 4.80 log10 cfu·ml^{-1} reported by Tsegelem *et al.* [25] for milk samples collected from the equipment of camel milk producers in Fafan zone. However, it was lower than the value (92.25×10^9 cfu·ml^{-1}) reported for raw milk samples collected from the equipment of milking camel in Afar zone [26]. The difference may be due to the difference in hygienic practices followed during milk production and postharvest handling. The hygienic practices performed during milk production and postharvest handling may varies according to the production system, adapted practices, level of awareness, and availability of resources [27].

The mean SPC for raw camel milk samples collected from both in udder (5.35 ± 0.15 log10 cfu·ml^{-1}) and milk equipment (6.72 ± 0.15 log10 cfu·ml^{-1}) in the study area are higher than the upper acceptable limit (5 log10 cfu·ml^{-1} of raw milk) given by Marshall [28] and O'Connor [29]. This may be due to poor storage temperature, long storage period after milking, health and hygiene of the camel, environment where milking is done as well as procedures used in cleaning and sanitizing the milking and storage equipment.

3.1.2. Total Coliform Count

Similar to SPC, the production system significantly ($P < 0.01$) affect total coliform count (TCC) of raw camel milk samples collected both from udder and milk equipment. Thus, the mean TCC for raw milk samples collected from the udder of milking camels in pastoral production system (3.14 ± 0.18 log10 cfu·ml^{-1}) was significantly higher ($P < 0.01$) than in agro-pastoral production system (2.03 ± 0.15 log10 cfu·ml^{-1}) (Table 2). Moreover, raw milk samples collected from the

Table 2. Least square mean (±SE) total coliform count (log10 cfu·ml^{-1}) of raw camel milk samples collected in the study area.

Variables	Total coliform count
Production system (n = 40)	***
Pastoral	4.18 ± 0.15^{a}
Agro-pastoral	3.12 ± 0.15^{b}
Milk sources (n = 40)	***
Milk equipment	4.71 ± 0.16^{a}
Udder	2.59 ± 0.16^{b}
Production system * milk sources	**
Pastoral * milk equipment	5.21 ± 0.20^{a}
Agro-pastoral * milk equipment	4.20 ± 0.20^{b}
Pastoral * udder	3.14 ± 0.20^{c}
Agro-pastoral * udder	2.03 ± 0.20^{d}
Overall mean	**3.65 ± 0.19**

n = number of samples taken; significance: **P < 0.01, ***P < 0.001; SE. = Standard error.

storage equipments in the pastoral production system (5.21 ± 0.20 log10 cfu·ml^{-1}) was significantly higher (P < 0.01) than in agro-pastoral production system (4.20 ± 0.24 log10 cfu·ml^{-1}). Such significant difference in between two production system may be due to the difference in awareness on hygienic practices (like cleaning of utensils, washing milker's hands, personal hygiene, quality of water used for hygienic practices, washing the udder, use of individual towels) performed during milk production and postharvest handling. Moreover, such differences might be due to the variation in health and hygiene of milking camel between two production systems.

Milk source had significant (P < 0.01) effect on TCC; and thus, the mean TCC for raw camel milk samples collected from milk equipment was significantly (P < 0.001) higher than that for udder milk samples (Table 2). This might be due to further contamination of the milk during storage and transportation. Moreover, lack of cooling system and longer time elapsed during milk storage and transportation in the study area could contribute to such increasing trends.

The mean TCC (2.59 ± 0.16 log10 cfu·ml^{-1}) for raw milk samples collected from the udders (Table 2) was lower than the value (4.4 log10 cfu·ml^{-1}) reported for raw milk samples collected from the udder of milking camel in Ab'aladestrict [26]. This variation may be due to herd hygiene, water sources, and sanitation for milking practices. However, it was comparable with the value (2.83 log10 cfu·ml^{-1}) reported for raw milk samples collected from the udder of milking camel in Switzerland [30].

The mean TCC (4.71 ± 0.23 log10 cfu·ml^{-1}) for milk samples collected from milk handling equipment of producers (Table 2) was higher than the value (3.84 log10 cfu·ml^{-1}) reported for raw milk samples collected from milk handling

equipment of producers in Afar [31]. However, it was lower than the value (6.75 log10 cfu·ml^{-1}) reported by Morocco [32] and Benyagoub *et al.* [33] for raw milk samples collected from milk handling equipment in south west Algeria (6.75 log10 cfu·ml^{-1}). Such variations could be due to the differences in herd health management practices at farm, hygiene of milking procedures, type and quality of milk equipment used, personal hygiene of milk producers, udder heath, quality of water used for hygienic practices and others.

The upper acceptable limit of TCC for raw milk is 2.18 log10 cfu·ml^{-1} [34]. However, the overall mean counts for raw camel milk samples collected both from the udder (2.59 ± 0.16 log10 cfu·ml^{-1}) and milk equipment (4.71 ± 0.16 log10 cfu·ml^{-1}) in the study area exceeded the upper acceptable limit. This might be due to poor herd/farmhygiene and health care management practices performed by smallholder milk producers. Gamal *et al.* [35] indicated that poor hygienic practices during milk production and postharvest handlings enable the milk to have high microbial counts than the upper acceptable limit and make the milk unsafe for its intended use.

3.1.3. Yeast and Mould Count

The mean YMC of raw milk samples were significantly ($P < 0.01$) influenced by milk source and production system interaction (**Table 3**). Thus, raw camel milk sample collected from pastoral production system had significantly higher mean YMC than samples collected from agro-pastoral production system for both samples collected from the udder and milk equipment. Moreover, raw milk samples collected from milk equipment had significantly higher mean YMC than samples collected from udder of milking camel in both production systems.

Table 3. Least square mean (±SE) yeast and mold count (log10 cfu·ml^{-1}) of raw camel milk samples collected across the production system and milk sources.

Variables	Yeast and mold count
Production system ($n = 40$)	***
Pastoral	2.56 ± 0.11^{a}
Agro-pastoral	1.86 ± 0.11^{b}
Milk sources ($n = 40$)	***
Milk equipment	2.65 ± 0.12^{a}
Udder	1.71± 0.12^{b}
Production system * milk sources	**
Pastoral * milk equipment	2.96 ± 0.14^{a}
Agro-pastoral * milk equipment	2.18 ± 0.14^{b}
Pastoral * udder	1.96 ± 0.14^{bc}
Agro-pastoral * udder	1.64 ± 0.14^{c}
Overall mean	**2.18 ± 0.13**

n = number of samples taken; significance: **$P < 0.01$, ***$P < 0.001$, SE. = Standard error.

The average yeast and mould count (YMC) for raw milk samples collected from the udder of milking camels in pastoral production system (0.95 ± 0.12 log10 cfu·ml^{-1}) was significantly higher ($P < 0.05$) than in agro-pastoral production system (0.68 ± 0.10 log10 cfu·ml^{-1}) (Table 3). Moreover, raw milk samples collected from milk equipment in the pastoral production system (2.16 ± 0.20 log10 cfu·ml^{-1}) was significantly higher ($P < 0.05$) than in agro-pastoral production system (1.05 ± 0.23 log10 cfu·ml^{-1}). This may be due to variation in milk storage temperature, quality of water used for hygienic practices and health condition of milking camel as well as variation in knowledge on hygienic milk production and postharvest handling practices in between two production systems.

The mean YMC of raw camel milk samples were significantly ($P < 0.01$) influenced by milk source (Table 3). Thus, raw milk samples collected from the udder (0.82 ± 0.12 log10 cfu·ml^{-1}) were significantly ($P < 0.01$) lower than samples collected from the equipment of producers (1.61 ± 0.12 log10 cfu·ml^{-1}) (Table 3). This might be due to further contamination of the milk during storage and transportation. Moreover, lack of cooling system and longer time elapsed during milk storage and transportation could contribute for such higher count.

The mean YMC (1.21. ± 0.16 log10 cfu·ml^{-1}) for milk samples collected from the udders and equipment of producers (Table 3) was agrees with Alaoui *et al.* [36] who reported yeast and mould count of 1.6 log10 cfu·ml^{-1} for raw camel milk in Morocco. This difference might be due to the variation in the hygienic conditions of milk environment, cleanliness of udders and teats before milking, hygiene of milk handlers' hands, sanitary conditions of milk equipment and quality of water used for hygienic practices. Moreover, the presence or absence of cooling facilities during milk storage and transportation might contribute such difference.

According to Torkar and Vengust [37], the upper acceptable limit of YMC for raw milk is 1.7 log10 cfu·ml^{-1}. However, the mean YMC for raw camel milk samples collected from the udders (1.71 ± 0.12 log10 cfu·ml^{-1}) and milk equipment (2.65 ± 0.12 log10 cfu·ml^{-1}) exceeded the upper acceptable limit. This might be due to contamination from dust, air, containers, water used and poor personal hygiene. According to Frank (2001) the potential sources of contaminations of Yeast and Moulds are air, water and equipments and also occur during processing, packaging or storage of raw materials or finished products.

The presence of YMC in raw milk above the recommended upper limit is an indication of unhygienic condition during production and postharvest handling as well as failure to use cooling system during storage and transportation, and makes the milk unsafe for its intended use [37].

4. Conclusion and Recommendation

The study indicated that raw camel milk samples collected from udder and milk equipment in pastoral production system had significantly higher microbial count than samples collected from agro-pastoral production system. Moreover, there

were significant differences in microbial counts between raw camel milk samples collected from udder and milk equipment in both production systems, in that, samples collected from milk equipment had the higher microbial counts than samples from udder of lactating camel. The mean microbial counts of raw milk samples collected from the udders and equipment of producers in the study area exceeded the upper acceptable international limit. This shows that raw camel milk samples collected from two sources in the study area were substandard in their microbiological quality, and are unsafe for their intended uses. Therefore, the concerned governmental and non-governmental organization should pay great attention to the improvement of hygienic practices essential for safe milk production and handling through undertaking different relevant development interventions like awareness creation and capacity development of milk producers on general hygienic practices to be followed during milk production and post-harvest handling. Moreover, improving the health condition of milking camel through providing appropriate animal health extension services as well as providing better quality water in the study area is highly recommended.

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Conflicts of Interest

The authors declare no conflict of interest regarding the publication of this paper

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