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Hygienic Production Practices and Microbiological Quality of Sheep Milk in Ararso District of Jarar Zone, Somali Regional State, Ethiopia

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ABSTRACT

This study was conducted to evaluate the hygienic production practices and microbiological quality of sheep milk in Ararso district of Jarar Zone, Somali Regional State, Ethiopia. A stratified sampling strategy was used to choose 180 households specifically for this investigation. A total of 60 pooled raw sheep milk samples (each containing 200 mL) were collected from the udders and milk handling equipment of selected milk producers in the research area. The samples were examined to determine microbiological quality. The data were gathered via a questionnaire, field observation, key informant interviews, and focus group discussions. The vast majority of respondents in pastoral (86.7%) and agro-pastoral (64.4%) production systems were illiterate. The majority of respondents (70.6%) in the research area cleaned the sheep home (kraal) once every two days. The majority (98.3%) of respondents in the research area milk their sheep in open kraals with no roof or walls. As a consequence, 36.7% of pastoral and agro-pastoral respondents (81.1%) reported cleaning milk vessels on a regular basis. Almost all of the responders in the research area used plastic equipment for milking and handling. The majority of responders in pastoral and agro-pastoralist categories placed barn hygiene first, with indexes of 0.24 and 0.23, respectively. The average total bacterial count (TBC), coiform count (CC) and yeast and mould count (YMC) of raw sheep milk samples were 5.13±0.21, 2.89±0.27, and 0.77±0.21 $\log_{10}$ cfu/mL, respectively. Raw sheep milk samples taken from producers' milk handling equipment had a substantially higher mean total bacterial count (5.78±0.32 $\log_{10}$ cfu/mL) compared to samples collected from the udder (4.48±0.23 $\log_{10}$ cfu/mL). Milk samples from pastoral and agro-pastoral households had an average coliform count of 3.18 and 2.60 $\log_{10}$ cfu/mL, respectively. The average YMC in milk samples from pastoralists and agro-pastoralists were 0.74 and 0.80 $\log_{10}$ cfu/mL, respectively. In general, pastoralists and agro-pastoralists in the district do not practice hygienic milking and handling. Consequently, the implementation of hygienic milk production and handling practices is essential to enhance the safety and quality of sheep milk in the study area. Additionally, further research should be undertaken to investigate the microbiological aspects and assess the safety and quality parameters of sheep milk in greater detail.

INTRODUCTION

Ethiopia has significant potential in sheep that are raised using various production strategies. The country achieved 42.9 million sheep, with 70% females and 30% males. Ethiopia's sheep population is around 99.5% native, with hybrids and alien varieties accounting for 0.41% and 0.08%, respectively (CSA, 2021). The Blackhead Somali sheep is a widely dispersed sheep breed that is raised in dry and semiarid areas of southern Ethiopia. It is the region's leading sheep breed. Wan-kie is the local name for the breed, but it is also known globally as the Ogaden or Berbera Black-head sheep. According to CSA (2021), the Somali regional state possesses 11,013,491 heads.

Sheep, with their multi-faceted utility (meat, wool, skin, excrement, and, to some extent, milk), play an important role in the agricultural economy. They are better adapted to arid and semi-arid tropical zones with marginal and sub-marginal lands, and they thrive in dryland situations where there is little vegetation due to rangeland management and reseeded pastures (Singh and Sahoo, 2022).

In Ethiopia, cattle are the primary source of milk for human consumption, followed by camels (CSA, 2021). Small ruminants are mostly raised by smallholder farmers for meat, milk, and wool (FAO, 2009; Abebe *et al.*, 2013; Yitayew *et al.*, 2013). In Ethiopia's pastoral system, sheep are typically used for milk, meat, and skin (Getachew *et al.*, 2010; Mirkena *et al.*, 2011).

Although sheep milk has good nutritional and to some extent medicinal value, it provides a favorable environment (an excellent growth medium) for the growth of much different types of microorganisms especially after it loses its temporary germicidal or bacteriostatic properties (Bouazza *et al.*, 2012; Azeze *et al.*, 2015). It is well-known that aseptically drawn fresh milk from clean and healthy milking animals typically contains a low microbial count. However, unhygienic practices (such as poor farm environment, herd health management practices, housing conditions, milking procedures and personal hygiene of milkers) during milk production allow the milk to pick up many microbes at farm level. The use of contaminated water for hygiene practices as well as the use of poorly cleaned and maintained equipment during milking will

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also allow milk to pick a large number of microorganisms at farm level (Chambers, 2002). Moreover, unhygienic practices performed during post-harvest handling by milk actors across the milk supply chain will allow raw milk to pick a large number of microorganisms.

The risk of milk including sheep milk contamination with harmful microorganisms is high for milk produced in developing countries like Ethiopia as their milk production practices is traditional type, which lack appropriate hygienic measures (Gurmessa, 2014). The risk is high in lowland regions especially in pastoral and agro-pastoral area. 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 (Kalyankar *et al.*, 2016).

To protect sheep milk from microbial contamination and improve its nutritional value, documented information must be available on the hygienic production and handling procedures as well as the microbiological quality of sheep milk in the study area. Such information could be crucial for government, non-government and other development organizations to undertake reliable development activities that provide milk producers with a clear understanding of the hygienic practices essential for the production and handling of safe and quality milk. However, currently there is no well documented information on the hygienic production and handling procedures of sheep milk as well as the microbiological quality of sheep milk in the study area where sheep milk is consumed mainly by children and their subsequently sick family members. Therefore, this study was conducted to assess the hygienic production practices and microbial quality of raw sheep milk in Ararso District, Jarar Zone, Somali Region, Ethiopia.

MATERIALS AND METHODS

Description of the Study Area

The study was carried out in the Somali Regional State of Ethiopia's Ararso district, which is a part of the Jarar Zone. This district is situated 90 kilometers northwest of Jigjiga City and 711 kilometers east of Addis Ababa. Its geographic coordinates are latitude 43°37' N, longitude 8°70' E, and average elevation above sea level is 1,507 meters. The district's average annual maximum temperature is 35°C, while its average annual minimum temperature is 19°C. The region experiences bimodal patterns of rainfall, with the majority of the rainy seasons falling between April and June and October and December. There are also occasional Karan rains in July and September. There is a range of 448 to 669 millimeters of precipitation on average each year. The two main agricultural production systems in the Ararso district are pastoralism and agro-pastoralism, with the latter being more common. With significant numbers of sheep (78,557), goats (69,533), camels (21,351), and cattle (25,694), according to the district administration, livestock farming is essential to the local economy. The district has an overall population of 86,071, with roughly 44,757 males and 41,341 females, according to the Bureau of Finance and Economic Development (BoFED, 2018). About 74.02% of this population lives in rural areas, and 25.98 percent of them live in urban areas.

Study Design and Sampling Procedure

This study used a cross-sectional design that consisted of two sections: a survey and laboratory work. Survey work was done to gather pertinent data on sanitary procedures used in the production of sheep milk, and lab testing was done to assess the microbial quality of the milk. The Ararso district was divided into production systems categorized as agro-pastoral and pastoral. Every production system underwent additional stratification into rural kebeles (RKs). Six kebeles in total, three from pastoral and three from agro-pastoral production systems, were purposefully chosen for the study based on their highest potential for producing sheep milk. The administration of each country provided the lists of households that produced sheep milk. Lastly, 30 sheep milk producing households were chosen at random from each Kebeles. As a result, 180 sheep milk producers in the district were chosen to participate in the study of sheep milk production and handling practices (two production systems * 3K* 30 households). In accordance with the previously mentioned sampling stratification, samples of raw sheep milk were taken from the udders and the producer's equipment in order to assess the microbiological quality. About 120 sheep milk producer households-60 from each production system-of the 180 sheep milk producer households that were initially taken into consideration for the survey were taken into consideration for the raw sheep milk sample.

Data Collection Procedures

Following the process of stratification and household identification, in-depth group discussions were conducted with key informants from each production system, including leaders of the community, experts, and milk producers with a wealth of experience in the field under investigation. The aim was to gather data on the demographics of these households, as well as information on the district's postharvest handling and sheep milk production operations. With the help of the generated data, a survey questionnaire was created, pre-tested before being distributed, and then distributed. To gather additional data that was not adequately described in the questionnaire survey, field observations were conducted. The udder (n = 30; 10 from each kebele) and milk handling equipment of producers (n = 30; 10 from each kebele) were the sources of a total of 60 pooled raw sheep milk samples (each with a volume of 200 mL) for microbial quality analysis. The sampling stratification previously mentioned was followed. Sterile screw-capped sampling bottles were used to gather the raw sheep milk samples aseptically. Following a tight cap and marker labeling, the bottles were placed in an icebox (≤4OC)

until they were brought to the Haramaya University dairy technology lab and the Jigjiga Veterinary Regional Laboratory for microbial quality analysis, respectively. Once at the laboratory, the samples were stored in a refrigerator (with a temperature of 0–4°C) until the scheduled time.

Microbiological Analysis

Total Bacterial Count

Standard plate agar was used to calculate total bacterial counts. A sterile test tube holding 9 mL of sterile peptone water was filled with 1 mL of raw milk sample. Following a thorough mixing step, the suspension was serially diluted up to a 10^{-9} concentration. Duplicate samples from the appropriate dilution (1 mL) were then plated with 15-20 mL of melted standard plate counting agar solution that had cooled, and the mixture was again thoroughly mixed. The resultant plates were left to solidify before being incubated for 48 hours at 32 °C (Richardson, 1985). The standard plate count was determined by selecting plates containing colonies ranging from 30 to 300 colony forming units (CFU) mL^{-1} (Richardson, 1985). The formula supplied by IDF (2004) was used to calculate the standard count, which was defined as the total number of CFU per mL of milk sample.

$$N = \frac{\sum C}{(1*n1)+(0.1*n2)*d}$$

Where, N = Number of colonies per ml of milk sample
∑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.

Total Coliform Count

Sterile violet red bile agar (VRBA) was used to calculate the total coliform count (TCC). Nine milliliters of sterile peptone water and one milliliter of raw milk sample were placed in a sterile test tube. Following thorough mixing, duplicate samples (1 mL) were pour-plated using a sterile 15-20 mL VRBA (Oxoid, UK) after the suspension had been serially diluted up to 10-8. The resultant plates were thoroughly mixed, allowed to solidify, and then incubated for 24 hours at 32°C (Murphy, 1996). Coliforms were counted on the plates when typical dark red or purplish-red colonies showed up after incubation. According to Richardson (1985), growth and gas production during the incubation period were regarded as sufficient evidence of the presence of coliforms. IDF (2004) provided a formula for calculating total coliform counts on plates containing 15 to 150 cfu mL^{-1} (Kiiyukia, 2003).

Yeast and Mold Count

To determine the yeast and mold count (YMC), sterile Potato Dextrose Agar (PDA) was used. Nine milliliters of sterile peptone water and one milliliter of raw milk sample were placed in a sterile test tube. Following thorough mixing, duplicate samples of 0-point 1 mL were spread-plated on surfaces of media containing PDA that had been pre-dried (Oxoid, UK). The suspension was then serially diluted up to 10-7. After that, the plates were incubated for five days at 25OC (Richardson, 1985). Yeasts are defined as creamy to white/gray colonies, while molds are defined as filamentous (fuzzy) colonies of different colors, such as yellow, green, and light brown (Yousef and Carlstrom, 2003). When it became difficult to tell whether some colonies were made of yeast or mold, a microscopic analysis was performed with the oil immersion objective to determine whether the cells in the colonies were unicellular or multicellular. Using the formula supplied by IDF (2004), plates containing 10 to 150 colonies will be utilized to calculate the counts of yeast and mold (IDF, 2008).

Data Analysis

SPSS (version 20) was used to analyze the data. To look at the variations between categorical variables, the chi-square test was used. Furthermore, prior to statistical analysis, the microbial count data (expressed as colony forming units per milliliter) was converted into logarithmic scales (log_{10}) and examined using the SAS (2009) procedure. Using Tukey's adjustment, the mean comparison was performed. At the significance level of $P<0.05$, the difference was deemed noteworthy. The following model were used analysis: -

$Y_{ij} = \mu + \alpha_i + e_{ij}$

Where, Y_{ij} = individual observation for each test
μ = the overall mean
α_i = the effect of ith production system (i=2; pastoral & agro-pastoral)
e_{ij} = random error (the error term)

RESULTS AND DISCUSSION

Demographic Characteristics of the Households

Table 1 presents the respondents' demographic information from the study areas. In both the pastoral (65.6%) and agro-pastoral (58.9%) production systems, the majority of respondents were female; the remaining respondents (34.4%) and (41.1%) were male. The average age of the participants was 42.18±11.02 years. 75.5% of respondents were illiterate overall, with 15.6% attending religious schools, 6.7 percent in primary schools, and 4.4 percent in secondary schools. The majority of respondents in pastoral (86.7%) and agro-pastoral (64.4%) production systems were illiterate. The study's findings revealed a significant difference in educational status between the agro-pastoralists and pastoralists in the study area, with a significance level of $P<0.05$. The results also suggested that illiteracy was more prevalent in the pastoral areas. This study's findings are consistent with those of Hassen *et al.* (2022). who found that the percentage of the population lacking literacy in the Dagahbour district of the Jarar zone is higher. Education clearly plays a significant role in influencing household income, the adoption of new technologies, demographics, health, and the overall socioeconomic status of the family (Kerealem, 2005). Wendimu (2013) found that the percentage of the

population lacking literacy in religious schools in the Gode and Adadile districts of the Somali region is higher. In addition, inadequate knowledge and training regarding hygienic milk production and postharvest handling practices exposes raw milk to microbial contamination (Omore *et al.*, 2005) The average family size in the household was 6.66±2.

Table 1: Sex, age, educational level and family size of the respondents

Variables	Pastoral		Agro-pastoral		Total of overall		X^2	P-value
Sex	**N**	**%**	**N**	**%**	**N**	**%**		
Male	31	34.4	37	41.1	68	37.8		0.3
Female	59	65.6	53	58.9	112	62.2		
Age (years) (mean ±SD)	**43.18±10.9**		**41.19±11.4**		**42.18±11.2**			
Educational level								
Illiterate	78	86.7	58	64.4	136	75.5		<.0001
Primary school	0		12	13.3	12	6.7		
Secondary school	0		4	4.4	4	4.4		
Religious school	12	13.3	16	17.8	28	15.6		
Family size (mean ±SD)	**6.54±2.74**		**6.77±2.91**		**6.66±2.82**			

SD=standard deviation

Housing and Cleaning Practices

The analysis of housing types and cleaning practices in the study area reveals some key differences between pastoral and agro-pastoral households. The data shows that nearly all households, regardless of their production system, use wood as the primary material for constructing their homes. Specifically, 100% of pastoral households and 96.7% of agro-pastoral households rely on wood, indicating a strong preference or necessity for this material, likely due to its availability and affordability. Only a small number of agro-pastoral households (3.3%) use stone or bricks, suggesting that such materials are less commonly used or accessible in these communities. In terms of cleaning practices, there is a notable difference between the two systems. A higher proportion of agro-pastoral households clean their barns daily (26.7%) compared to pastoral households (11.1%). The most common cleaning frequency for both groups is once every two days, with 76.7% of pastoral and 64.4% of agro-pastoral households following this practice. Only a small percentage of households clean their barns once every three days. The difference in cleaning frequency is statistically significant (P = 0.02), suggesting that agro-pastoral households have more rigorous hygiene practices than pastoral households. This could be due to a greater awareness of the importance of sanitation, better access to resources, or a higher level of livestock management intensity in agro-pastoral systems. The results of this study align with those of Hassen *et al.* (2022), who observed that most pastoralists and agro-pastoralists in the Degahbur region do not clean their animal shelters on a daily basis.

Table 2: Housing type and cleaning practices in the study area

Housing type	Pastoral		Agro-pastoral		Overall		P
	N	%	N	%	N	%	
Type of housing materials							
Wood	90	100	87	96.7	177	98.3	0.08
Stone/bricks	0	0	3	3.3	3	1.7	
Frequency of cleaning barn							
Daily	10	11.1	24	26.7	34	18.9	
Once in two days	69	76.7	58	64.4	127	70.6	
Once in three days	11	12.2	8	8.9	19	10.6	0.02

N= Number of respondents

Hygienic Milking and Handling Practices

Hygienic Milking Practices During Milking

Table 3 illustrates hygienic milking and handling means. All responders said they milked their ewes twice a day, in the morning and in the evening. The majority of respondents in the study region (98.3%) milk their sheep in open kraals with no roof or walls, whereas 1.7% milk their sheep outside of the kraals. This suggests that milk might be contaminated with muck and animal excrement, particularly during the rainy season, increasing the likelihood of milk contamination and spoiling. The study found that 1.1% of respondents washed their

udders before milking. This could be due to a lack of awareness, and it could become a potential cause of milk contamination with hazardous germs. Lack of udder cleaning measures prior to milking may allow spoilage and pathogenic bacteria to enter milk during milking, and failure to wash the udder prior to milking will surely expose milk to microbial contamination (Mohammed *et al.*, 2016). Furthermore, this study found that approximately 92.2% of pastoralists and 88.9% of agro-pastoralists did not wash their hands before milking. This is comparable with the study of Hassen *et al.* (2022) who reported that majority of pastoralists (93.3%) and agro-pastoralists (75%) Degahbur area did not wash their hands before milking. FSA (2006) indicated that milk producers should properly wash udders and their hand before start milking as such practices highly minimizes milk contamination with harmful microorganisms. According to Kurwijila (2006), using unclean hands while milking significantly increases the microbial content of milk. This is because such activities aid in the transfer of visible and non-visible dirt from inadequately cleansed hands into the milking container while milking. According to the study, sheep milked inside open kraals with no roofs, walls, or milking barns. As a result, farmers in the study locations milked their animals in undesignated, poorly kept barns, making milk prone to contamination and spoiling. Milking in an open area may enable pollutants into the milk, resulting in a high spoiling rate (Kahuta, 2013).

Table 3: Milking frequency and hygienic practices during milking

Parameters	Pastoral		Agro-pastoral		Overall		X^2	P
	N	%	N	%	N	%		
Milking frequency								
Once a day	0	0	0	0	0	0		
Twice a day	90	100	90	100	180	100		
Three times a day	0	0	0	0	0	0		
Who is engaged in milking								
Children	17	18.	11	12.2	28	15.6		
Women	73	81.1	79	87.8	152	84.4		
Men	0	0	0	0	0	0		
Where do you milk the Ewes								
In barn	90	100	87	96.7	177	98.3		0.08
Outside of barn	0	0	3	3.3	3	1.7		
Hand milking								
Hand washing before milking								
yes	7	7.8	10	11.1	17	9.4	0.585[a]	0.30
No	83	92.2	80	88.9	163	90.6		
Udder washing								
Udder washing before milking	0	0	2	2.2	2	1.1		0.49
No washing at all	90	100	88	97.8	178	98.9		
Drying under after washing								
Yes	0	0	0	0	0	0		
No	90	100	90	100	180	100		

N= number of respondents

Milking Equipment, and Cleaning Practices

Table 4 summarizes the milking equipment, smoking, and cleaning routines. As a consequence, 36.7% of pastoral and agro-pastoral respondents (81.1%) cleaned milk vessels on a regular basis using cold water and no soap. The study found a significant difference ($p<0.05$) between the two production systems, indicating that cleaning milk vessels is more common in agro-pastoral areas than pastoral areas. This contradicts Haile *et al.*'s (2012) finding that 85.6% of respondents used hot water to clean milk-handling equipment in Hawassa City. This variation could be attributed to urbanization, as rural areas did not receive any hygiene-related training. Almost all responders (100%) in the research area used plastic milking and handling equipment, which is inappropriate and can contribute to milk contamination and spoiling. Furthermore, the information gathered from key informant interviews and focus group discussions suggested that the recommended and adequate milk equipment was not used in the area due to its accessibility and affordability. Lumadede *et al.* (2010) reported the same findings.

Furthermore, Omore (2005) stated that because stainless steel milk containers are expensive, Kenyan milk producers utilize plastic containers that are difficult to clean and disinfect, perhaps contributing to low milk

quality. The remaining milk and other dirt particles within the container may contaminate the milk. According to Omore *et al.* (2005), the main reasons for the poor quality of raw milk sold by producers and informal milk merchants include a lack of formal training and the usage of plastic containers. The use of plastic equipment is not recommended since the surface is readily scratched by standard cleaning systems, making cleaning difficult and providing hiding places for bacteria. This permits bacteria to multiply during milk handling intervals, potentially leading to microbial contamination of milk during milking and handling (Omore *et al.*, 2005).

The majority of respondents in pastoral areas (91.1%) and agro-pastoral (94.4%) fumigated milking equipment with smoke from burning stems of specific plant species, such as Boscia minimifolia (Maygaag), Blanites galabra (Kadi), and Capparis decidua (Irir). In general, 98.2% of pastoral and agro-pastoral respondents used smoking to improve taste and flavor while also increasing milk shelf life. Among the plant materials used to smoke. Boscia minimifolia is the most widely utilized, followed by Blanites galabra, because of the aroma it imparts to the product, which is well-liked by consumers in the research region. The findings of this study are consistent with those of Hassen *et al.* (2022), who reported that the majority of respondents in the Degahbour district used smoking to improve taste and flavor as well as to extend the shelf life of milk.

Furthermore, the findings are consistent with those of Negash *et al.* (2012), who found that around 93.3% of respondents smoked their milk handling equipment to improve the flavor and scent of milk and milk products in Ethiopia's mid-rift valley. Smoking milking equipment with herbs is utilized in Kenyan pastoral communities to clean milking equipment, improve milk quality, and lengthen shelf life (Wafula *et al.*, 2016). Furthermore, because smoking has antimicrobial properties, it prevents the growth of germs in milk, increasing its shelf life (Mogessie *et al.*, 1993). Similarly, Fita *et al.* (2004) demonstrated that smoking milk vessels with burning wood chips from specific trees and shrubs has the advantage of imparting a unique taste and odor to the product, as well as disinfecting the vessels, reducing the number of microorganisms and extending the product's shelf life. The majority of respondents (78.9%) did not use milk vessel cleaners, whereas 12.8% and 8.3% used hot water and Omo to clean milk vessels, respectively. The majority of the water utilized to clean the milking equipment came from the barka and ponds, which were the primary sources of water in the research region.

Table 4: Milking equipment and cleaning practices in the study area

Parameters	Pastoral		Agro-pastoral		Overall		X^2	P
	N	%	N	%	N	%		
Cleaning milk vessels regularly								
Yes	33	36.7[b]	73	81.1[a]	106	58.9	36.716[a]	<0.0001
No	57	63.3[a]	17	18.9[b]	74	41.1		
Milking equipment and milk storages.								
Plastic material	90	100	90	100	180	100		
Wood materials	0	0	0	0	0	0		
Clay pot	0	0	0	0	0	0		
Smoking milk containers								
Yes	82	91.1	85	94.4	167	92.8	0.746[a]	0.5
No	8	8.9	5	5.6	13	7.2		
Purpose of smoking containers								
Give good flora and aroma	26	28.9[a]	14	15.6[b]	40	22,2	7.827[a]	0.02
Increase the shelf life	16	17.8[a]	10	11.1[b]	26	14.4		
Both	48	53.3[b]	66	73.3[a]	144	63.3		
Plants used for smoking								
Boscia minimifolia (Maygaag)	76	84.4[a]	68	75.6[b]	144	80	2.225[a]	0.32
Blanites galabra (kadi)	12	13.3[b]	19	21.1[a]	31	17.2		
Capparis decidua (Irir)	2	2.2	3	3.3	5	2.8		
Use of detergent when cleaning milk equipment								
Yes	11	12.2[b]	27	30	38	21.1[b]	8.540[a]	0.003
No	79	87.8[a]	63	70	142	78.9[a]		
Type of used cleaners								
Soap	0	0	0	0	0	0		<0.0001
soap (Omo)	3	3.3[b]	12	13.3[b]	15	8.3		

Chemical cleaners	0	0	0	0	0	0		
Hot water	8	8.9[a]	15	16.7[a]	23	12.8		

Means followed by different superscript letters within a row are significantly different at P<0.05, N= Number of respondents

Major Constrains of Hygienic Sheep Milk Production

Table 5 summarizes the major constraints to hygienic sheep milk production in the research area. The majority of pastoral and agro-pastoralist respondents placed barn hygiene first, with indexes of 0.24 and 0.23, respectively, as the most significant concern contributing to milk contamination in the research locations. The findings of this investigation are consistent with Ruegg (2006) found that exposing the teat end to organic bedding sources, wet and muddy pens increase the risk of mastitis and milk contamination. According to Ahmed *et al.* (2022), the primary restrictions to hygienic goat milk in Dagahbour district were poor barn cleanliness, poor production techniques, disease, a source of washing water, and a lack of extension services. As a result, inadequate hygienic production is another barrier to sheep milk hygiene production. Barn hygiene, poor hygienic production, source of washing water, illnesses and parasites, lack of veterinary service, and lack of market were identified as the primary sheep milk hygienic restrictions in the study area. Poor hygienic milk production (unclean udder due to lack of washing before milking, unclean hands, poor personal hygiene and health status, unclean milking containers due to lack of clean water, and unclean milking sites) is more likely to cause milk-borne diseases, and natural antimicrobial factors can only provide limited protection against specific pathogens for a short period of time. These findings are consistent with Mohammed *et al.* (2016), who observed that milk-borne disease is more prevalent when milk is drank raw, as is customary practice among local producers. Furthermore, Yeserah *et al.* (2020) identified inadequate hygiene conditions, such as unclean milking equipment, as one of the key barriers to milk production in Ethiopia.

Table 5: Major constrains of hygienic sheep milk production in the study area

Variables	Pastoral							Agro-pastoral						
	R_1	R_2	R_3	R_4	R_5	R_6	Index	R_1	R_2	R_3	R_4	R_5	R_6	Index
Poor barn hygienic	59	10	9	5	2	3	0.24	68	14	4	3	1	0	0.23
Poor hygienic production	10	46	7	4	4	1	0.19	13	57	4	2	0	0	0.19
Source of water	15	5	36	9	3	0	0.18	6	8	43	12	2	0	0.18
Diseases and parasites	3	5	4	30	14	4	0.16	3	2	20	37	5	1	0.17
Lack of veterinary service	0	2	5	7	25	6	0.12	0	1	1	8	29	10	0.13
Lack of market	1	3	4	5	7	18	0.10	0	1	2	4	5	20	0.08

Index = [(5 for rank 1) + (4 for rank 2) + (3 for rank 3) + (2 for rank 4) + (1 for rank 5)] divided by the sum of all constraints of sheep production mentioned by the pastoralist, R = Rank

Microbiological Quality of Sheep Milk

Total Bacterial Count

Table 6 shows that raw sheep milk samples obtained from producers' milk handling equipment had a substantially higher mean total bacterial count (5.78±0.32 $\log_{10}$ cfu/mL) compared to samples collected from the udder (4.48±0.23 $\log_{10}$ cfu/mL). This could be attributed to the use of dirty and inefficient milking equipment. Raw sheep milk samples collected from pastoral production systems had a higher mean TBC (5.58±0.13 $\log_{10}$ cfu/mL) compared to agro-pastoral production systems (4.68±0.41 $\log_{10}$ cfu/mL) (P<0.05). This could also be related to inappropriate and unsanitary milking operations, animal health and hygiene, and milk equipment cleaning procedures. According to O'Connor (1994), the permitted limit of TBC for raw milk is 5 $\log_{10}$ cfu/mL, which is lower than the current data (5.13 $\log_{10}$ cfu/mL). This could be attributed to inadequate farm/herd hygiene and health care management procedures used by smallholder milk producers. Furthermore, failure to use chilling facilities during milk storage and transit, as well as a prolonged storage period following milking, could be the primary causes of TBC exceeding the upper permitted limit. The greater TBC was caused by poor hygiene and sanitation methods, such as not cleaning the udder and teats before milking, and incorrect hygiene techniques lead to microbial contamination during milking. Mohammadi *et al.* (2013) revealed that milk quality is determined by its composition and sanitary measures used during milking processes, such as the cleanliness of milking equipment, transportation and storage conditions, and the cleanliness of the individual animal's udder.

Table 6: Least square mean (±SE) TBC ($\log_{10}$cfu·mL^{-1}) of sheep milk samples in the study area

Milk source	N	Pastoral	Agro-pastoral	Overall	P
Udder	30	4.94±0.08[a]	4.02±0.38[b]	4.48±0.23	0.002
Equipment	30	6.23±0.18[a]	5.34±0.45[b]	5.78±0.32	

Overall	**60**	**5.58±0.13**	**4.68±0.41**	**5.13±0.27**	

Means followed by different superscript letters within a row are significantly different at P< 0.05, n = number of samples, SE = standard error, TBC = total bacterial count

Total Coliform Count

Raw sheep milk samples taken from udders had a lower mean total coliform count (TCC) of 2.38±0.36 $\log_{10}$ cfu/mL (P<0.05) compared to samples collected from milk handling equipment with a mean count of 3.41±0.21 $\log_{10}$ cfu/mL (Table 7). This could be attributed to the use of dirty and inefficient milking equipment. Table 7 shows that raw sheep milk samples obtained from pastoral production systems had a higher mean TCC (3.19±0.20 $\log_{10}$ cfu/mL) than those collected from agro-pastoral production systems (2.60±0.37 $\log_{10}$ cfu/mL^{-1}) (P<0.05). This could be due to unsanitary conditions such as unclean equipment, contact with sheep manure while milking, and personal hygiene of the milking personnel. Fernandes (2009) suggested a limit of fewer than 2 $\log_{10}$ cfu/mL for TCC in raw milk, which is lower than the current data (2.89±0.27 $\log_{10}$ cfu/mL). This could be due to poor farm hygiene, the use of contaminated equipment, improper milking procedures, a lack of awareness among milk producers, poor herd hygiene, the use of polluted water for hygienic procedures, a lack of cooling facilities during milk storage, etc. Abo El Makarem (2016) made similar suggestions.

Table 7: Least square mean (±SE) TCC ($\log_{10}$cfu·mL−1) of sheep milk samples in the study area

Milk source	N	Pastoral	Agro-pastoral	Overall	P
Udder	30	2.65±0.15^{a}	2.12±0.57^{b}	2.38±0.36	0.004
Equipment	30	3.74±0.25^{a}	3.08±0.17^{b}	3.41±0.21	
Overall	**60**	**3.19±0.20**	**2.60±0.37**	**2.89±0.27**	

Means followed by different superscript letters within a row are significantly different at P< 0.05, n = number of samples, SE = standard error, CC = coliform count

Yeast and Mold Count

The yeast and mould count (YMC) of milk samples collected from the pastoralists and agro-pastoralists in the study area is given in Table 8. The overall average YMC in the current study was 0.77 $\log_{10}$ cfu/ml. Hussein (2016) reported yeast and mould count of 5.4x10^{-3} cfu/ml for sheep breed in Egypt. Yeast and Moulds are considered as spoilage organisms. The high count of yeasts and moulds in this study might be due to poor hygiene of equipment's during handling of milk and it indicates unsanitary conditions of handling and contamination from the environment. Frank (2001) indicated that the potential sources of contaminations of Yeast and Moulds are air, water; equipment has and also occur during processing, packaging or storage of raw materials or finished products.

Table 8: Least square mean (±SE) YMC ($\log_{10}$cfu·mL^{-1}) of sheep milk samples in the study area

Milk source	N	Pastoral	Agro-pastoral	Overall	P
Udder	30	0.64±0.15	0.72±0.20	0.68±0.18	0.008
Equipment	30	0.84±0.24	0.88±0.25	0.86±0.24	
Overall	**60**	**0.74±0.20**	**0.80±0.22**	**0.77±0.21**	

Means followed by different superscript letters within a row are significantly different at P<0.05, n = number of samples, SE = standard error, YMC = yeast and mold count

CONCLUSION

Majority of the respondents in both production systems in the study area were illiterate which indicated that they had a limited awareness and knowledge of hygienic milk production procedures. The sheep were milked inside open kraals, which could raise the possibility of milk contamination and spoilage. Majority of respondents did not wash their hands and the udder of the animal prior to milking, which indicating low community awareness and knowledge of hygienic milk production and handling practices. Plastic equipment's is which difficulty to clean and increase milk contamination and spoilage were used for milking and milk handling. The main obstacles to producing hygienic sheep milk in the study area were poor barn hygienic and poor hygienic procedures. The microbial load of raw sheep milk samples collected from the udder and as well as from equipment of the study area exceeded the upper acceptable international limits, this shows the raw sheep milk samples collected from different sources in the current study were substandard in their microbiological quality and are unsafe for their intended uses. Based on above conclusion, the study recommendations Awareness creation and trainings are needed for the community about the importance of hygienic milk production and handling practices, Proper hygienic handling of milk should be practiced through washing of milking containers, udder washing, pasteurizing milk, use of proper containers instead of wooden materials. In addition, further investigations with a wider area's coverage are required to identify the different species of microorganisms that might cause public health hazards.

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