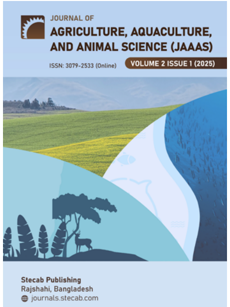

Journal of Agriculture, Aquaculture, and Animal Science (JAAAS)
ISSN: 3079-2533 (Online)
Volume 2 Issue 1, (2025)
https://doi.org/10.69739/jaaas.v2i1.359
https://journals.stecab.com/jaaas

Published by
Stecab Publishing

Research Article

Production Practices and Physiochemical Quality of Sheep Milk in Ararso District of Jarar Zone, Somali Region, Ethiopia

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About Article

Article History
Submission: February 21, 2025
Acceptance : March 19, 2025
Publication : March 25, 2025

Keywords
Ararso, Physiochemical Quality, Production Practices, Sheep Milk

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ABSTRACT

This study aimed to evaluate the production methods and physicochemical properties of sheep milk in the Ararso District of Jarar Zone, Somali Regional State, Ethiopia. A total of 180 households were purposively selected through a stratified sampling approach. Additionally, 60 pooled raw sheep milk samples were collected for analysis of physicochemical properties. Data collection involved questionnaires, field observations, interviews with key informants, and focus group discussions. A significant proportion of the respondents, 86.7% in pastoral systems and 64.4% in agro-pastoral systems, were illiterate. The primary reason for keeping sheep in both systems was income generation, with indices of 0.23 for pastoral and 0.24 for agro-pastoral systems. During the wet season, the main feed for sheep in both systems came from communal natural pasture (88.9%), followed by private natural pasture (22.2%). In the dry season, the primary feed sources included private natural pasture (56.7%), communal natural pasture (32.2%), and a mixture of crop residue and natural pasture (11.1%). Regarding water sources, the majority of respondents (56.1%) in both systems identified springs as the main water source during the wet season, followed by dams/ponds (32.2%) and barkas (11.7%). However, these water sources decreased during the dry season. During the dry season, barkas became the predominant water source (76.7%), followed by boreholes (17.2%) and dams/ponds (6.1%). Significant differences ($P < 0.05$) were observed in the availability of water sources between the pastoral and agro-pastoral systems, with barkas, boreholes, and dams/ponds being the major water sources in both systems. Sheep were typically housed in open kraals, which do not offer adequate protection from harsh environmental conditions. The average pH, density, and titratable acidity of the milk samples were 6.51, 1.032 g/ml, and 0.19%, respectively. The average values for total solids, fat, protein, and lactose content were 17.48%, 5.99%, 5.24%, and 4.65%, respectively. Significant differences ($P < 0.05$) were found between the pastoral and agro-pastoral systems regarding milk quality. The study suggests that improving hygienic practices in milk production and handling could enhance the quality of sheep milk in the area. Furthermore, additional research on sheep milk quality is recommended.

Citation Style:

Ali, A., Abdimahad, K., & Abdilahi, A. (2025). Production Practices and Physiochemical Quality of Sheep Milk in Ararso District of Jarar Zone, Somali Region, Ethiopia. *Journal of Agriculture, Aquaculture, and Animal Science, 2*(1), 82-91. https://doi.org/10.69739/jaaas.v2i1.359

1. INTRODUCTION

Ethiopia possesses considerable potential for sheep farming, with the country housing approximately 42.9 million sheep. Of this population, 70% are females, and 30% are males. The majority of the sheep population in Ethiopia (99.5%) is native, while only a small proportion (0.41% and 0.08%) comprises hybrids and exotic breeds (CSA, 2021).

One of the most common breeds of sheep in the country is the Blackhead Somali, widely distributed across the arid and semi-arid regions in southeastern Ethiopia. Locally known as Wankie, this breed is also recognized internationally by names such as Ogaden and Berbera Blackhead sheep. The Somali Regional State alone has a sheep population of 11,013,491 (CSA, 2021).

In Ararso District, small ruminant farming, particularly sheep, plays a vital role in the agricultural system, offering small-scale farmers a crucial source of income, especially during crop failures. With increasing costs, sheep and goat farming has expanded, particularly among younger, landless individuals in both pastoral and agro-pastoral systems.

Sheep milk has been a valuable food source for millennia, with historical evidence suggesting its consumption predates many other forms of milk (Zervas & Tsiplakou, 2011). Sheep milk is closely comparable to human milk in its fatty acid composition, making it a viable raw material for infant formula production (Martin *et al.*, 2016). Compared to cow and goat milk, sheep milk is more nutrient-dense, with higher levels of fat, protein, total solids, and essential vitamins and minerals (Heinlein, 2004). Its superior digestibility, due to smaller fat globules, also contributes to its higher biological value compared to cow milk (Barłowska *et al.*, 2011).

In terms of essential amino acids, sheep milk contains more than cow's milk, including higher levels of valine, isoleucine, leucine, lysine, tryptophan, methionine, threonine, and phenylalanine (Chernyshova, 2013). It also contains greater amounts of vitamins A, D, E, and B-complex than cow and goat milk (Park *et al.*, 2007; Alexopoulos *et al.*, 2011).

Moreover, sheep milk has higher levels of conjugated linoleic acid (CLA), a compound known for its cancer-fighting and fat-reducing properties, compared to milk from other mammals, including cows, goats, pigs, horses, and humans (Barłowska *et al.*, 2011). Its mineral content, particularly calcium, phosphorus, magnesium, and trace elements like iron, copper, and manganese, varies more than cow milk, with higher levels of zinc, which is important for skin health and improved digestibility (Park *et al.*, 2007; Barłowska *et al.*, 2011). Additionally, sheep milk is often better tolerated by individuals allergic to cow milk (Heinlein, 2004). Due to its superior nutritional and medicinal properties, sheep milk is frequently used to nourish malnourished individuals, particularly in lowland areas, more so than cow milk (Heinlein, 2004).

Despite its nutritional advantages, sheep milk is susceptible to microbial contamination due to the loss of its bacteriostatic properties over time (Bouazza *et al.*, 2012; Azeze *et al.*, 2015). Although milk drawn aseptically from clean animals generally has a low microbial count, poor farm conditions, inadequate herd health management, unclean milking equipment, and improper milking practices can lead to contamination (Torkar & Teger, 2008). Additionally, the use of contaminated water and unhygienic postharvest handling practices can further increase the risk of spoilage and health hazards (Chambers, 2002; Mattias, 2013).

Milk, a yellowish-white liquid secreted by mammary glands, is rich in essential nutrients like carbohydrates, proteins, fats, minerals, and vitamins (Pandey and Voskuil, 2011). It is considered the ideal food for young mammals before they can digest other types of food (Olatunji *et al.*, 2012). Globally, milk production primarily comes from cattle, camels, goats, sheep, and buffalo, with cattle contributing to about 85% of total milk production. Sheep milk constitutes approximately 1.4% of global milk output (FAO, 2016). While cow milk dominates worldwide, sheep milk plays an essential role in pastoral and agro-pastoral systems, especially in regions where climatic conditions favor sheep farming, and its higher nutritional value stands out (FAO, 2016). Factors such as lactation stage, breed, and health of the animal influence milk composition, making comparisons across different studies challenging (Kalyankar *et al.*, 2016).

However, there is limited documented information about sheep milk production practices, handling, and the physicochemical quality of sheep milk in Ethiopia. This gap led to the conduction of the present study, which aims to assess both the production practices and the physicochemical quality of raw sheep milk in the Ararso District of Jarar Zone, Somali Regional State, Ethiopia.

2. LITERATURE REVIEW

2.1. Sheep Milk Production and Utilization

Globally, sheep and goat milk contribute 36.5% and 63.5%, respectively, to the total small ruminant milk output (FAO, 2017). While any sheep breed can technically be milked, certain breeds are recognized for their superior milk production potential (FAO, 2017). The average lactation period for dairy sheep ranges from 180 to 240 days, whereas non-dairy breeds typically lactate for 90 to 120 days. Sheep milk is mainly processed into cultured dairy products like cheese and yogurt rather than consumed fresh due to its high fat and total solids content. China stands as the leading global producer of sheep milk. The milk's composition plays a crucial role in determining the quality of derived dairy products such as cheese, butter, and ghee. Globally, sheep milk yields approximately 680.3 million kilograms of cheese and 63.25 million kilograms of butter and ghee annually (FAO, 2016).

2.2. Milk and Milk Products Handling Practices and Safety

Milk and milk products are a staple food worldwide, but they are highly susceptible to contamination by microorganisms once they leave the udder. Therefore, proper milk handling practices, including sanitation of the milking environment and hygiene of the milker and equipment, are essential to prevent spoilage (Tsedey & Asrat, 2015). In Ethiopia, milk handling practices often fail to meet hygienic standards due to inadequate pre-milking practices, such as failing to wash the udder with clean water, and post-milking issues like improper storage, prolonged storage, and use of inappropriate containers. Plastic containers, for instance, increase the risk of contamination due to their unsuitability for milk handling, while traditional clay pots harbor bacteria that lead to spoilage (Tsedey & Asrat, 2015). Furthermore, dairy producers often use local fumigation methods, such as smoking milking utensils with aromatic plants, to extend the shelf life of milk by reducing bacterial contamination (Tsedey & Asrat, 2015; Ismail *et al.*, 2024).

Milk, though highly nutritious, is prone to contamination by physical, chemical, and microbiological hazards. Milk quality is determined by characteristics such as chemical composition, specific gravity, and microbial content, while the safety of milk products depends on the absence of pathogenic organisms and other contaminants that pose health risks (Merwan *et al.*, 2018). Quality control is essential to ensure the safety and acceptability of milk and milk products, with microbial quality and chemical composition being key determinants.

2.3. Sheep Milk Composition

The chemical composition of milk varies across species, influenced by factors such as breed, diet, environmental conditions, stage of lactation, and udder health (Giambra *et al.*, 2014; Kapadiya *et al.*, 2016). Sheep milk differs from cow and goat milk not only in its composition but also in its secretion mechanism. Sheep exhibit an apocrine milk secretion style, contributing to a higher somatic cell count (SCC) compared to cows, which secrete milk merocrinely (Caldwell, 2014). Additionally, sheep possess smaller udder cisterns and only two teats, unlike cows.

Haenlein and Wendorff (2006) emphasize that sheep milk production is predominantly seasonal, in contrast to the year-round breeding cycles of cows - making the season a key factor influencing milk composition. Sheep milk generally contains 18.3% total solids, 6.0% fat, 12.3% solid-not-fat (SNF), 4.9% lactose, 0.94% ash, and 5.2% protein — significantly richer than cow milk, which holds 12.5% total solids, 3.8% fat, 8.7% SNF, 4.6% lactose, 0.8% ash, and 3.1% protein (Kanwal *et al.*, 2004). Sheep colostrum also exhibits higher nutrient content compared to cow colostrum, with 13.0% fat versus 5.1%, 11.8% protein versus 7.1%, and 28.9% total solids versus 15.6% (Anifantakis, 1986).

Sheep milk is renowned for its richness in proteins, minerals (calcium, phosphate, magnesium), and medium-chain fatty acids, making it particularly suitable for cheese and yogurt production (Zhang *et al.*, 2006; Barłowska *et al.*, 2011). Moreover, it contains elevated levels of unsaturated fatty acids, iron, and phosphorus compared to cow milk. Lactose levels in sheep milk tend to be lower at the beginning (colostrum stage) and end of lactation, while fat and protein concentrations peak during these periods (Pulina and Bencini, 2004; Haenlein and Wendorff, 2006). Casoli *et al.* (1989) highlighted breed-related variations in sheep milk composition, with fat content ranging from 4.6% in Iraqi Kurdi sheep to 12.6% in American Dorset sheep. Protein content showed less variation, from 4.8% in Grade Precoce to 7.2% in Armenian Corriedale sheep.

2.4. Physico-Chemical Property of Sheep Milk

Sheep milk displays unique physico-chemical properties compared to cow and goat milk. It has higher specific gravity, viscosity, titratable acidity, and refractive index, coupled with a lower freezing point (Haenlein & Wendorff, 2006; Park *et al.*, 2007). The increased viscosity is attributed to its elevated total solids content, which positively influences yogurt curd firmness (Jumah *et al.*, 2001). Additionally, the enhanced water-binding capacity of sheep milk proteins may contribute to its higher viscosity (Labropoulos *et al.*, 1984).

3. METHODOLOGY

3.1. Description of the Study Area

The study was conducted in Ararso District, located in the Jarar Zone of the Somali Regional State, Ethiopia. The district is situated 711 km east of Addis Ababa and 90 km northwest of Jigjiga city. Its geographical coordinates are 43°37’N and 8°70’E, with an average elevation of 1,507 meters above sea level. The area experiences an average annual maximum temperature of 35°C and a minimum temperature of 19°C. The rainfall pattern in the district is bimodal, with rainfalls occurring from April to June and October to December, while occasional Karan rains may occur between July and September. The mean annual rainfall ranges from 448 mm to 669 mm (SC-UK, 2015). The predominant agricultural systems in the district are pastoralism and agro-pastoralism, with agro-pastoralism being the most common (SCUK/DPPB, 2004). Livestock, particularly sheep (78,557), goats (69,533), camels (21,351), and cattle (25,694), play an integral role in the livelihoods of the district’s residents. According to the BoFED (2018), the district has a total population of 86,071, with 44,757 men and 41,341 women. About 74.0% of the population lives in rural areas, while 25.98% reside in urban areas.

3.2. Study Design

This research employed a cross-sectional design, which consisted of two main components: a survey and laboratory analysis. The survey was conducted to gather information on hygienic sheep milk production practices, while laboratory tests were performed to evaluate the physicochemical quality of raw sheep milk in the study area.

3.3. Sampling Technique

Ararso District was stratified based on the two primary livestock production systems: pastoral and agro-pastoral. Each system was further divided into rural kebeles (local administrative units). Six kebeles (three from the pastoral and three from the agro-pastoral systems) with the highest potential for sheep milk production were purposively selected for the study. A list of sheep milk-producing households was obtained from the respective local administrations. From these, 30 households from each kebele were randomly selected, resulting in a total of 180 households (three kebeles from each production system, with 30 households per kebele). In total, 120 households (60 from each production system) were chosen for the collection of raw sheep milk samples.

3.4. Data Collection Procedures

After the stratification and identification of milk producer households, focus group discussions were conducted with key informants, such as experienced milk producers, community leaders, and experts, in each production system. These discussions provided demographic information about the sheep milk producers and insights into their sheep milk production and postharvest handling practices. This information was used to develop a survey questionnaire, which was pre-tested before its administration. The survey was then conducted, and additional data were collected through field observations when certain details were not adequately captured by the questionnaire.

For the laboratory analysis, 60 pooled raw sheep milk samples (30 from each production system) were collected from the selected milk producers. The milk samples were collected aseptically using sterile screw-capped sampling bottles, which were securely closed, labeled, and placed in iceboxes (maintained at ≤4°C) for transport. The samples were then delivered to the Dairy Technology Laboratory at Haramaya University for analysis. Upon arrival, the samples were stored in a refrigerator (maintained at 0-4°C) until analysis, which was performed within 24 hours of collection.

3.5. Chemical Composition Analysis

The chemical composition of the raw sheep milk, including fat, protein, total solids, lactose, solids-not-fat (SNF), and some physical properties such as density and titratable acidity, were determined using the Milkoscan FT1. For analysis, 60 mL of each milk sample was placed into the sample holder of the Milkoscan FT1, one sample at a time. The instrument was activated, and the milk was drawn for measurement. The results were displayed on the device screen. The pH of each sample was measured using a calibrated pH meter before the analysis.

3.6. Data Analysis

Data collected using the questionnaire survey and field observations were analyzed using SPSS (version, 20). Descriptive statistics was used to quantitatively express the responses of the study participants with respect to their demographic characteristics as well as their sheep milk production and handling practices. Chi-square test was employed to examine the differences among categorical variables. The differences were considered to be significant at the level P<0.05. Moreover, data on physicochemical quality was analyzed using the procedure of SAS (2009). The mean comparison was made using Tukey's adjustment. The difference was considered to be significant at the level P<0.05. The following models were used for physicochemical quality 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)

4. RESULTS AND DISCUSSION

4.1. Demographic Characteristics of the Respondents

The demographic characteristics of the respondents in the study area are summarized in Table 1. In both the pastoral (65.6%) and agro-pastoral (58.9%) production systems, the majority of respondents were females, with the remaining respondents being males (34.4% in the pastoral system and 41.1% in the agro-pastoral system). The overall average age of the respondents was 42.18 ± 11.2 years.

In terms of education, a large proportion of respondents in both pastoral (86.7%) and agro-pastoral (64.4%) production systems were illiterate. Overall, 75.5% of the respondents were illiterate, while 15.6% had attended religious schools, 6.7% had completed primary school, and 4.4% had attended secondary school. Statistical analysis revealed a significant difference (P < 0.05) in the educational status between the two production systems, with a higher proportion of illiteracy observed in the pastoral areas. This finding is consistent with the study by Hassen *et al.* (2022), which reported higher illiteracy rates in the Dagahbour district of the Jarar Zone. The level of education has a clear impact on household income, technology adoption, health, and overall socio-economic status (Kerealem, 2005). Similarly, Wendimu (2013) reported a higher proportion of illiteracy and attendance at religious schools in Gode and Adadile districts of the Somali Region. Additionally, the lack of education and training on hygienic milk production and postharvest handling increases the risk of microbial contamination in raw milk (Omore *et al.*, 2005).

The average household size in the study area was 6.66 ± 2.82 members, which is consistent with the average family size of the Somali Region, which was reported to be around 6.7 persons per household (CSA, 2007).

Table 1. Sex, age and educational level 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

4.2. Purposes of Keeping Sheep

The purposes for keeping sheep in the study area are outlined in Table 2. The primary reason for keeping sheep in both pastoral and agro-pastoral systems was income generation, with indices of 0.23 and 0.24, respectively. The income generated primarily comes from the sale of live animals, and the cash earned is used to purchase food, clothing, and other household necessities. The second most common reason for keeping sheep in both production systems was for milk production, with indices of 0.22 and 0.23, respectively. Meat was ranked third in both systems, followed by saving, which ranked fourth, with indices of 0.2 and 0.19, respectively. Social and cultural functions were ranked fifth, with indices of 0.12 and 0.11 in the pastoral and agro-pastoral systems, respectively. These findings are consistent with the study by Abdilahi *et al.* (2022), who reported that the primary reason for keeping sheep in the pastoral and agro-pastoral systems of Awbarre District, Fafen Zone, was income generation. Similarly, Fsahatsion *et al.* (2013) found that the primary reason for keeping sheep in the Gamogofa Zone of southern Ethiopia was income generation. Feyissa *et al.* (2018) also noted that milk was the third most important purpose for keeping sheep in the Borana lowland areas. Furthermore, Hailemariam *et al.* (2013) reported that the main reason for keeping sheep in the Gamogofa Zone was also income generation.

Table 2. Purposes of keeping sheep in the study area

Purposes	Priority choice													
	N	Pastoral						N	Agro-pastoral					
		R1	R2	R3	R4	R5	Index		R1	R2	R3	R4	R5	Index
Income	90	62	6	13	9	0	0.23	90	64	4	14	6	2	0.24
Saving	76	6	13	15	36	6	0.2	72	6	10	38	3	15	0.19
Milk	87	11	46	12	11	7	0.22	88	9	44	16	12	7	0.23
Meat	80	8	12	39	3	18	0.21	82	12	16	9	41	4	0.22
Social & cultural	47	3	8	4	4	28	0.12	42	1	8	4	1	28	0.11

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 weighed purposes of sheep keeping mentioned by the respondents, R=Rank

4.3. Major Feed Resources

The major feed resources in the study areas are summarized in Table 3. During the wet season, the primary feed source for sheep in both pastoral and agro-pastoral systems was communal natural pasture (88.9%), followed by private natural pasture (22.2%). There was a significant difference ($P < 0.05$) in the availability of feed resources during the wet season between the two production systems. The higher proportion of communal natural pasture was found in the pastoral area, whereas a higher proportion of private natural pasture was reported in the agro-pastoral area. This difference can be attributed to the fact that in the agro-pastoral system, land is mostly privately owned, and crop cultivation is practiced alongside livestock farming. Similar findings were reported by Fsahatsion *et al.* (2013) in the Gamogofa Zone, southern Ethiopia. During the dry season, the main feed sources reported were private natural pasture (56.7%) and communal natural pasture (32.2%), with 11.1% of sheep in the study area being fed a mixture of natural pasture and crop residue. The study also found significant differences ($P < 0.05$) in the availability of feed resources during the dry season between the two production systems.

Table 3. Major feed sources in wet and dry season in the study area

Feed source	Pastoral		Agro-pastoral		Overall		P
	N	%	N	%	N	%	
Wet season							
Communal natural pasture	90	100a	70	77.8b	160	88.9	
Private natural pasture	0	0	20	22.2	20	22.2	
Dry season							
Communal natural pasture	58	64.4	0	0	58	32.2	
Private natural pasture	31	34.4	71	78.9	102	56.7	
Natural pasture with Crop residue	1	1.1	19	21.1	20	11.1	

Means followed by different superscript letters in the same row are significantly different at (P<0.05), N= Number of respondents.

4.4. Water Sources and Availability

The sources of water during the wet and dry seasons are presented in Table 4. During the wet season, the majority of respondents in both the pastoral and agro-pastoral systems (56.1%) reported that springs were the primary water source, followed by dams/ponds (32.2%) and barkas (11.7%). However, the availability of these water sources declines significantly during the dry season. In the dry season, barkas become the main water source, as reported by the majority of respondents (76.7%), followed by boreholes (17.2%) and dams/ponds (6.1%). There was a significant difference (P < 0.05) in the availability of water sources during the dry season between the two production systems. This indicates that barkas, boreholes, and dams/ponds were the primary water sources in both production systems. This finding contrasts with the report of Demissu and Gobena (2015), who identified rivers as the major water source for Horro sheep in the Horro Guduru and East Wollega Zones of western Ethiopia. The discrepancy may be attributed to the availability of rivers in their study area, as well as potential agro-ecological differences between the two systems.

Table 4. Source of water during wet and dry seasons in the study area

Parameters	Pastoral		Agro-pastoral		Overall		P
	N	%	N	%	N	%	
Water source (wet season)							
Barka	6	6.7	15	16.7	21	11.7	0.05
Wells (bore holes)	0	0	0	0	0	0	
Dam/pond	27	30	31	34.4	58	32.2	
Springs.	57	63.3	44	48.9	101	56.1	
Water source (Dry season)							
Barka	75	83.3	63	70	138	76.7	0.010
Well (bore hole)	8	8.9	23	25.6	31	17.2	
Dam/pond	7	7.8	4	4.4	11	6.1	
springs	0	0	0	0	0	0	

Means fallowed by different Superscript letters in the same row are significantly different at (P<0.05), N=Number of respondents

4.5. Type of Housing and Cleaning Practices

The type of housing and its cleaning practices are summarized in Tables 5. Proper housing is essential for protecting animals from predators, theft, and adverse weather conditions. In the study area, most respondents (97.2%) housed their sheep together with goats, while a few (2.8%) housed sheep alone in an open kraal, which was enclosed with thorny acacia trees. These findings align with those of Wendimu (2013), who reported that most pastoralists and agro-pastoralists in Gode Zone also housed their sheep with goats. Similarly, Fikru and Omer (2015) found that all farmers in Awbare District housed their sheep in open kraals, and Legese *et al.* (2014) reported that farmers in Shinile District used open-top fences for housing all animals. The primary purposes of sheep housing in the study area were to protect the animals from predators, extreme weather at night, theft, and to facilitate easier husbandry practices. Regarding cleaning practices, the majority of respondents (70.6%) cleaned their sheep housing (kraals) once every two days, while 18.9% cleaned it daily and 10.6% cleaned it every three days. The frequency of cleaning depended on the availability of labor and the season of the year (Table 5). The study found that all the observed kraals lacked roofs, were constructed on earth floors, and had poor drainage, making them difficult to clean. During the rainy season, kraals often became contaminated with mud and urine. This resulted in soiling of the teats, udders, flanks, and other body parts of milking sheep while they were lying in the muddy kraals. Such conditions increase the risk of microbial contamination of milk during milking, particularly when the udder and teats were not adequately cleaned before milking.

Table 5. Housing type of the study area

housing type	Pastoral		Agro-pastoral		Overall		P
	N	%	N	%	N	%	
Sheep are housed							
Alone	5	5.6	0	0	5	2.8	0.05
With goats	85	94.4	85	94.4	175	97.2	
With cattle	0	0	0	0	0	0	
All livestock are housed together	0	0	0	0	0	0	

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	
Are lambs housed with sheep							
Yes	0	0	0	0	0	0	
No	90	100	90	100	180	100	
Do you clean the house of sheep							
Yes	90	100	90	100	180	100	
No	0	0	0	0	0	0	
Cleaning frequency							
Daily	10	11.1	24	26.7	34	18.9	
Once in two days	69	76.7	58	64.4	127	70.6	0.02
Once in three days	11	12.2	8	8.9	19	10.6	

N= Number of respondents

4.6. Physicochemical Properties of Sheep Milk

The chemical composition of sheep milk, including constituents like fat, protein, total solids, solids non-fat (SNF), and lactose, as well as some physical properties from the study areas, are summarized in Table 9. The results revealed significant differences (P<0.05) in fat, protein, SNF, and lactose levels between milk samples from the pastoral and agro-pastoral production systems. In terms of fat content, milk from the pastoral production system had a higher average (6.38±0.16) compared to the agro-pastoral system, where it was lower (5.61±0.12). The overall average fat content found in this study was 5.99%, which aligns closely with the 6% fat reported by Bezaye (2016) for sheep breeds in Arsi Negele.

Table 6. Mean ±SE of physicochemical properties of sheep milk samples

Variables	Pastoral (n=30)	Agro-pastoral (n=30)	Overall (N=60)
	Mean ±SE	Mean ±SE	Mean ±SE
Fat (%)	6.38± 0.16a	5.61±0.12b	5.99±0.14
Protein (%)	5.12±0.12	5.36±0.13	5.24±0.12
SNF (%)	11.94±0.14a	11.02±0.08b	11.48±0.11
TS (%)	17.55±0.46a	17.40±0.38a	17.48±0.42
Lactose (%)	4.69±0.02	4.61±0.04	4.65±0.03
Density (g/cm3)	1.030±0.00b	1.035±0.00a	1.032±0.00
TA*	0.18±0.003b	0.20±0.003a	0.19±0.003
pH	6.67±0.12	6.36±0.15	6.51±0.13

*Means followed by different superscript letters within a row are significantly different at (P<0.05), TS= Total Solids, SNF= Solids Non-Fat, TA=Titratable Acidity, n= number of samples taken, SE= Standard error, *= expressed as % lactic acid.*

The protein content of the milk samples from agro-pastoralists was found to be statistically similar (P>0.05) to that of the milk samples from pastoralists. The average protein content observed in this study (5.24%) was higher than the 4.82% reported by Bezaye (2016) for sheep in Arsi Negele, but lower than the 5.83% reported by Merlin *et al.* (2015) for Lacaune sheep in South Brazil. These differences could be attributed to variations in breed, production systems, and feed availability.

The average total solids (TS) content of sheep milk in the study area was found to be 17.48%. No significant differences (P>0.05) in TS content were observed between the milk samples from pastoral and agro-pastoral systems. The TS content in this study was higher than the 16.79% reported for sheep in Sudan (Ali *et al.*, 2017), but comparable to the 17.40% reported by Bezaye (2016) in Arsi Negele.

The SNF content was found to be 11.94% for pastoralists and 11.02% for agro-pastoralists, showing a significant difference (P<0.05). The overall SNF content (11.48%) in this study was lower than the 13.04% reported by Hussein (2016) for sheep in Egypt, but higher than the 9.95% reported by Ali *et al.* (2017) for sheep in Sudan. Alexopoulos *et al.* (2011) also reported a lower SNF content of 10.95% in sheep from Greece.

The mean lactose content of sheep milk in this study was 4.65%, which was lower than the 7.06% reported by Hussein (2016) for sheep in Egypt. It was also lower than the 5.22% reported by Ali *et al.* (2017) for sheep in Shumbat, Sudan. However, the lactose content in this study was higher than the 3.41% reported by Merlin *et al.* (2015) for Lacaune sheep in South Brazil.

The density of the milk samples from the pastoral production system was 1.031 g/ml, while the density from the agro-pastoral system was 1.035 g/ml, with a statistically significant difference (P<0.05). These variations could be due to differences in milk sources or possible adulteration. Previous studies by Bezaye (2016) and Merlin *et al.* (2015) reported sheep milk densities of 1.036 g/ml and 1.034 g/ml, respectively. Assenat (1991) indicated that sheep milk density tends to increase during mid-lactation and then decrease towards the end, reaching a density of 1.034 g/ml.

Titratable acidity (TA) is an indicator of milk freshness and bacterial activity. The TA of milk samples from agro-pastoralists was significantly (P<0.05) higher than that of pastoralists, indicating a higher level of bacterial activity in the former. The highest TA value (0.20%) was observed in milk samples from the agro-pastoral system, suggesting greater bacterial presence, while the lowest TA (0.18%) was observed in milk from the pastoral system, indicating better quality in terms of freshness. Mohamed *et al.* (2017) reported a TA value of 0.17% for sheep milk in Sudan.

The average pH of milk samples in this study was 6.51, which was lower than the 6.8 reported by Bezaye (2016). This lower pH could be due to rapid fermentation by lactic acid bacteria, especially in milk stored under high ambient temperatures. Generally, milk pH is used as an indicator of milk hygiene and usually ranges from 6.51 to 6.85, as noted by Ramos and Juarez (2011).

Milk composition and production result from a complex interaction between various factors, including genetics, environmental conditions, and management practices (O'Conner, 1994). The composition of milk is crucial for the production of dairy products like butter, cheese, and yogurt, as the yields of these products depend on the concentrations of milk's major constituents (O'Conner, 1994). Variations in sheep milk composition have been linked to several factors, such as breed, lactation stage, diet, milking procedures, and environmental conditions. For example, fat and total solids content often increases as lactation progresses, reaching up to 10% fat by the end of the lactation period (Kalyankar *et al.*, 2016). Other variables that influence milk composition include animal age, health, breed, and feeding practices (Kalyankar *et al.*, 2016).

5. CONCLUSION

This study concludes that the majority of respondents in both production systems in the study area were illiterate, which limited their awareness and knowledge of hygienic milk production procedures. Sheep were milked inside open kraals, increasing the risk of milk contamination and spoilage. The physicochemical properties of milk samples obtained from pastoralists and agro-pastoralists were within the acceptable standard levels established by different scholars, except for the fat content in milk from pastoral households. Therefore, to ensure the physicochemical quality of milk, particularly fat content, efforts should be made to improve the nutrition of lactating sheep through better pasture management and supplementary feeding. This will help maintain optimal milk composition and enhance its overall quality.

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