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ADDIS ABABA UNIVERSITY COLLEGE OF VETERINARY MEDICINE AND AGRICULTURE DEPARTMENT OF VETERINARY EPIDEMIOLOGYAND PUBLIC HEALTH (VEPH)

ASSESSMENT OF CAMEL MILK HANDLING PRACTICES AND BACTERIAL LOADS ALONG THE VALUE CHAIN IN BORANA AND EAST SHEWA, ETHIOPIA

BY

GELETU GUDETA DEKEBO

JUNE, 2026

BISHOFTU, ETHIOPIA

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ADVISOR: PROFESSOR BEKELE MEGERSA (DVM, MSC, PHD)

A Thesis submitted to the College of Veterinary Medicine and Agriculture of Addis Ababa University in partial fulfillment of the requirements for the degree of Master of Science in Veterinary Public Health

JUNE, 2026

BISHOFTU, ETHIOPIA

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ADDIS ABABA UNIVERSITY COLLEGE OF VETERINARY MEDICINE AND AGRICULTURE DEPARTMENT OF VETERINARY EPIDEMOLOGYAND PUBLIC HEALTH (VEPH)

As MSc research advisors, I certify that we have read and evaluated the thesis prepared under our guidance by **Geletu Gudeta Dekebo** entitled: "**Assessment of Camel Milk Handling Practices and Bacterial Loads Along the Value Chain in Borana and East Shewa, Ethiopia**" I recommend that it can be accepted as fulfilling the thesis requirement for the degree of Master of Science in Veterinary Public Health.

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Advisor Signature Date

DEDICATION

I dedicate this thesis to the loving memory of my beloved father Gudeta Dekebo, who passed away nine years ago under unknown circumstances. Although you are no longer with me, your love, guidance, and the values you instilled in me continue to inspire my journey every day.

STATEMENT OF AUTHOR

First, I declare that this thesis is my bona fide work and that all sources of material used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for an advanced MSc degree at Addis Ababa University, College of Veterinary Medicine and Agriculture and is deposited at the University/College library to be made available to borrowers under the rules of the library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

Name: Geletu Gudeta Dekebo Signature: _____

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LIST OF ABBREVIATIONS

ACE	Angiotensin converting enzyme
APC	Aerobic Plate Count
ASL	Above Sea Level
CC	Coliform Count
CFU	Colony Forming Unit
EU	European Union
FAO	Food and Agriculture Organization
IgG	Immunoglobulins G
KII	Key-Informant Interview
Km	kilometer
ML	Milliliter
Mm	Millimeter
SOP	Standard Operating Procedures
SUSCAMI	Sustainable Camel Milk Production

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ABSTRACT

Camel milk plays a vital role in the livelihood and food security of pastoral and agro-pastoral communities in Ethiopia, especially in Borana and East Shewa zones. However, poor milk handling practice compromises the quality and safety of milk along the value chain. A prospective longitudinal study was conducted from March 2025 to March 2026 to investigate hygienic milking, milk handling practices and microbial quality along the value chain in Borana and East Shewa. Milk handling practices were assessed through semi-structured interviews involving 48 camel milk producers, 20 collectors, 10 retailers, 10 cafeterias, 4 cooperatives, 20 consumers and 12 experts. A total of 752 samples with milk samples (n=472), hand swab (n=96) and container swab (n=184) samples were collected from both zones during the wet and dry seasons, and subjected to aerobic plate and coliform count. Results showed that while most producers never washed their hands (73%) or did not clean the udder (95.8%) before milking, post-milking hand washing was common (91%). In contrast, vessel hygiene practices were considerably better as nearly all producers washed (97.9%) and smoked (95.8%) their milk containers daily. All of the retailers and 60% of the collectors washed their hands with water and soap while handling milk. Nearly all of the value chain actors keep milk at room temperature until consumption. Regarding the awareness of food safety risks, experts demonstrated the highest awareness of foodborne diseases (83.3%), whereas boiling of milk especially for vulnerable groups, including children, elderly and pregnant women, is not a common practice. In both zones and seasons, the mean aerobic plate (7.47 log CFU/ml) and coliform (7.13 log CFU/ml) counts surpassed the Kenyan standard for raw camel milk. Bacterial contamination peaks at the retailer level, whereas relatively lower values recorded at the cafeterias and cooperative level. The overall mean aerobic plate counts and coliform counts increased in the wet season as compared to the dry season. Given the prevailing poor hygiene and limited food safety awareness, milk is exposed to contamination risks that require intervention measures in training and handling practices to enhance food safety.

Keywords: *Camel Milk, Microbial quality, Milk Handling, Milk Hygiene, Value Chain*

1. INTRODUCTION

1.1. Background

The world camel population was approximately 38.5 million head (FAO, 2020). Over 80% are found in Africa, with 60% of the population being in the Horn of Africa. Camels are predominantly found in countries like Somalia, Sudan, Niger, Kenya, Chad, Ethiopia, Mali, Mauritania, and Pakistan (Faye, 2020). Ethiopia's camel population has shown a significant increase in recent years, rising from 7.7 million in 2019 to over 8.1 million following a camel population readjustment in 2020 (Megersa *et al*.,2024).

Camel milk is a key food in arid and semi-arid areas of the African and Asian countries. The milk is traditionally consumed predominantly in its raw or fermented form (Abera *et al*., 2016). Mainly kept in a mobile grazing herders under pastoral production systems (Lamuka *et al*. 2017), and acts as a primary source of food and nutrition for pastoralists (Kebede *et al*. 2015; Mirkena *et al*. 2018). Beyond consumption by household (Gebremichael *et al*. 2019; Abbas *et al*. 2013), camel milk contributes to income security all year round (Amenu *et al*. 2019; Elhadi *et al*. 2015).

Milk from healthy udders is supposed to be free of pathogenic bacteria (FAO 2011). However, post-harvest milk contamination is common along the value chain in arid and semi-arid environments. This might be associated to the lack of clean cleaning water for utensils, absence of udder and milker's hand washing (Amenu *et al*. 2019), poor milking operation and storage conditions (Kaindi *et a*l. 2011) and lack of refrigeration facilities (Amenu *et al*. 2019) in pastoral areas which attributed to milk contamination along production to consumer (the value chain) (Kaindi *et al*. 2011). Milk handling in such environments without cooling in a fragile transportation conditions (Farah *et al*. 2007) results in further multiplication of contaminants including pathogenic microbial like S. aureus (Oliver *et al*. 2005; Owusu Kwarteng *et al*. 2020).

Quality of raw milk is a function of nutrition and health of the animal, chemical combination, and its microbial activities. The two dominant factors of the quality are the time before delivery to the consumer and condition of keeping the product. Microbial analysis of milk and milk products has been commonly performed using tests such as total

bacterial count, yeasts and molds, and coliform estimation. High bacterial load in aseptically drawn milk samples or detection of presence of harmful pathogenic microorganisms is an evidence of unhygienic milk production conditions (Kamal *et al*., 2010, Abdurahman, 2006).

There is a lack of knowledge, and hygienic handling practices in the camel milk production and processing in Ethiopia, along with the absence of established quality standards set for camel milk. This constitutes a high risk of microbial contamination of camel milk and subsequent infection of consumers by pathogenic microorganisms. The informal marketing of camel milk is a risk to consumers primarily because it is sold raw, unpasteurized, and without refrigeration. Handled in open, dusty environments using unsterilized plastic containers, this milk is highly susceptible to contamination with dangerous pathogens and toxins (Bekele *et al*., 2025).

1.2. Statement of the problem

Contamination of milk takes place during milking from the udder, from milking equipment or milking personnel. Furthermore, contamination and bacterial growth occurs during transportation and storage of the milk as milk is kept at room temperature under pastoral conditions. Under these conditions, microorganisms can contaminate milk and further multiply until consumption (Kamal *et al*., 2010, Abdurahman, 2006). As a result, milk is produced under unhygienic conditions leading to high microbial contamination and spoilage with associated health risks to consumers (Kamana *et al*., 2014).

In Ethiopia, especially in Borana and East Shewa region of the study areas, camel milk is produced in traditional ways and camels are milked under poor hygiene (Bekele *et al*., 2021). Then the milk is handled under poor hygienic conditions and transported a long distance where it is sold on the street or distributed to retailers to reach consumers. Thus, milk transported and handled under such conditions may have poor quality and contain pathogenic microorganisms of public health concern. Even though, there was research done on the camel milk by Abera *et al*, (2016) Fafan zone Somali region, Bekele *et al*, (2025) in Borana zone Oromia region, Amenu *et al*, (2019) in Borana zone Oromia region and others, there is no research done on the bacteriological quality of camel milk at various stages of the value chain, including milking, processing, and retail in East Shewa region.

This gap in knowledge can lead to health risks for consumers. Therefore, studying the quality and safety of raw camel milk along the milk value chain, i.e., from the production site until it reaches the milk consumers is very important. Understanding these dynamics is crucial for developing appropriate intervention strategies aimed at improving the quality and safety of camel milk produced in the study area, thereby enhancing its marketability and consumer trust.

Objectives

General objective

- ✓ This study was conducted to assess milk handling practices, and bacteriological quality of camel milk along the milk value chain in Borana and East Shewa

Specific objectives

- ✓ To investigate milk handling practices and hygienic measures along the value chain in Borana and east Shewa
- ✓ To assess the bacteriological quality of camel milk along value chain in Borana and East Shewa

2. LITERATURE REVIEW

The camel is a multi-purpose animal with high productive potential. In a time of global warming, growing deserts, and increasing scarcity of food and water camel is a potential candidate to overcome some of these problems. The camel is an excellent source of milk under these conditions. Indeed, countries like Afghanistan, Algeria, Ethiopia, Kenya, and Iran host large populations of camel, and therefore, its milk is an integral part of the human diet. Most of the camels are kept by pastoralists in subsistence production systems. They are very reliable milk producers during dry seasons and drought years, especially during milk scarcity from cattle, sheep, and goats (Panwar *et al*., 2015).

Camels are a source of food, cash income, and transport means and have significant cultural functions to pastoral communities dominating the arid and semi-arid lands (Guliye *et al*., 2007; Mahmoud, 2010). Camels play diverse roles in pastoralists' livelihood serving as building of assets, insurance against unexpected events, having spiritual and social values, traction and movement of goods, food supply, and income (Ali *et al*., 2010). Drier areas of the country like Afar, Somali region, and the eastern and southern parts of the Oromia region contain the majority of the camels. According to Sisay and Awoke (2015), annual camel milk production in Ethiopia is estimated to be 170,000 tons which ranked the country fourth next to Somalia, Kenya, and Mali in Africa in milk production. The economic viability of camels in arid lands is assured by their comparative advantages in their ability to adapt and remain productive under harsh climatic conditions, more than other livestock (Noor *et al*., 2013).

2.1. Camel milk consumption practices and uses

Milk is a highly nutritious food for human beings universally recognized as nature's nearly complete diet since it meets the complete nutritional requirements of neonates (Benta and Habtamu, 2011). Camel milk plays a vital role in household food security, prevention of malnutrition and acts as a source of cash to camel keepers and traders. It is an essential constituent of human diet in many parts of the world as well as in the pastoral and agro-pastoral areas of Borana (Dejene, 2015).

Camel milk is a source of high-quality protein and essential amino acids that support tissue repair and metabolic function. It provides key micronutrients including calcium,

potassium, zinc, and iron, and contains vitamin C at concentrations approximately three to five times higher than cow's milk, which is particularly valuable in arid regions with limited access to fresh produce (Swelum *et al*., 2021; Singh *et al*., 2024). Camel milk contains several bioactive proteins, including lactoferrin, immunoglobulins, lysozyme, and antioxidant peptides, which contribute to immune modulation and antimicrobial activity (Swelum *et al*., 2021; Muthukumaran *et al*., 2023).

Camel milk contains bioactive peptides, vitamins, and trace minerals that contribute to antioxidant defense by reducing oxidative stress. Whey proteins such as lactoferrin and lysozyme exhibit antimicrobial and iron-chelating properties that may limit pathogen growth, along with angiotensin-I-converting enzyme (ACE)-inhibitory peptides that may support vascular and metabolic health. Camel milk immunoglobulins, primarily IgG, are structurally smaller than those in bovine milk and may enhance intestinal absorption and immune signaling. Lactoferrin further contributes to immune regulation through anti-inflammatory and antimicrobial pathways (Swelum *et al*., 2021; Muthukumaran *et al*., 2023).

The market orientation of the livestock production system, especially milk, would secure the livelihoods and food supply to the rapidly growing non-farming community, create employment opportunities, and promote economic development in pastoral societies. However, in Ethiopia, the milk marketing system is not particularly well developed, and market access in the pastoral production system is a critical factor (Tola, 2002). Improving and enhancing the development of smallholder pastoralists to reach markets and involve them in marketing activities poses a pressing development challenge (Ahmed, 2003).

2.2. Camel milk composition and nutritive values

Camel milk is considered a very healthy drink because of low fat and cholesterol level. The milk consists of enough nutrients to sustain a person healthy throughout the day without consumption of any other foods. Normally it is opaque white in color with normal odor sweet and sharp taste, but sometimes it is salty due to various physiological factors (Fox 2003).

Moisture and protein have been observed to be higher as compared to fat content. Therefore, camel milk can exert definite health benefits on human host (Mal and Pathak,

2010; Konuspayeva *et al*., 2009). In addition, it is rich source of minerals, vitamins, enzymes, fatty acids etc.

Various minerals viz., Na, K, Ca, P Mg Fe, Zn, Cu and vitamins (A, E, C and B1) are present in camel milk (Onjoro *et al*., 2003; Khasmi *et al*., 2001). The concentration of vitamin C in camel milk is 2-3 times higher as compared to cow milk. The low pH due to higher concentration of vitamin C, stabilizes the milk and therefore it can be kept for relatively longer periods without cream layer formation. The availability of relatively higher amount of vitamin C in camel milk is of significant relevance from the nutritional point of view as it exerts powerful anti-oxidant activity (Mal *et al*., 2007).

2.3. Camel milking and milk handling practices

Milk is produced from pastorally managed camels, under traditional conditions, and camels are milked by hand. Large volumes of camel milk is produced and sold daily in the area. However, the milk is not pasteurized, handled under poor hygienic conditions, transported long distance without a refrigeration system and sold on open markets or distributed to retailers. Thus, milk transported and handled under such conditions would have poor quality and may contain pathogenic microorganisms of public health concern (Adugna *et al*., 2013).

Handling practices in pastoral communities often lack standardization and in most pastoral communities, milking is performed manually. Handlers may not wash their hands before milking, leading to contamination from dirt and bacteria present on their skin. Studies highlight that milking is typically done manually, with minimal hygiene protocols (Yosef *et al.*, 2025). A significant factor affecting milk quality is cleanliness of the udder before milking and unwashed udders contribute to high bacterial counts in raw camel milk.

After milking, the prompt cooling of milk is crucial to inhibit bacterial however, many pastoralists lack access to refrigeration. Simple cooling methods such as placing containers in cool water or using traditional cooling pots can help extend the shelf life of milk. Containers used for milking and storage, such as calabashes or plastic buckets, are rarely sterilized, increasing microbial contamination risks and plastic buckets is easy to transport, they can scratch easy and providing surfaces for bacteria to thrive (Yosef *et al*., 2025).

During transportation, camel milk frequently exposed to dust, dirt and high temperatures that lead to increasing spoilage and contamination. Longer transportation times can lead to prolonged exposure to unsuitable condition. A study in Somali Region, Ethiopia, found high bacterial counts in raw camel milk linked to unwashed udders and handlers. Handling practices for camel milk in pastoral communities are often inadequate, leading to risks of contamination and spoilage. By adopting better hygiene practices, improving storage and transportation conditions, and providing education on proper handling techniques, the safety and quality of camel milk can significantly enhanced (Mohammed., 2025).

2.4. Camel milk contaminations and major bacterial pathogens

Contamination of milk takes place during milking from the udder, milking equipment or from milking personnel. Furthermore, contamination occurs during transportation and storage of the milk. Under any of these conditions, microorganisms get into the milk and multiply. The microbial load of milk is determined by the distance between the farm, the processing plant and the consumers, the time lapsed during transportation of milk from the farm to the consumers, and the temperature of milk during storage and transportation which gives bacteria the chance to adapt and grow in this nutritious liquid (Semereab & Molla, 2001).

In Ethiopia, most of the camel milk is consumed in the raw state without any heat treatments (Seifu, 2007; Yohannes and Gebru, 2007). Contaminations can occur along the chain from producers to final consumers and the consumption of raw camel milk should be of major concern from a public health point of view (Musinga *et al*., 2008).

The problem of milk spoilage is one of the great concerns that occurs mainly due to adequate clean water and milk handling practices, which causes plastic containers to be commonly used for milk storage and transportation from household production and milk collection center areas to the markets. These types of containers are not easy to clean, and their mouths are very small and therefore cause milk spoilage even when washed with hot water (Omer and Ateye, 2023).

Moreover, camel milk is a highly nutritious medium permissive for the growth of many diverse bacterial species. The nutritional composition of camel milk, rich in proteins, vitamins, and minerals, creates an environment that not only nurtures beneficial

microorganisms but also enables the proliferation of harmful pathogens if not handled properly. This feature of camel milk highlights the importance of implementing stringent hygiene and processing standards throughout the production chain to ensure safety and maintain the product's quality (Rahmeh *et al*., 2019).

Pathogenic bacteria may present in raw milk as a direct consequence of udder disease. Total number of organism in milk as disease causative agent in relation to its proper evaluation for consumption is important. The notable disease causing bacteria in milk are Salmonella, Brucella, Staphylococcus, Listeria and coliforms. Coliforms are normal inhabitants of the large intestine and their presence in milk could indicate fecal contamination (Vahedi *et al*., 2013).

2.5. Potential Public health risks of raw camel milk consumptions

Non-heat-treated milk and raw milk products are the major factors responsible for illnesses caused by food-borne pathogens as numerous epidemiological reports have implicated (De Buyser *et al*., 2001). Foodborne diseases are among the most prevalent public health problems in the world (Ahmed *et al*., 2024). The presence of these pathogenic bacteria in milk is a public health concern, particularly for people who drink raw unpasteurized milk (Tusa *et al*., 2024). In particular, newborns and young children, elderly individuals, pregnant women, and people with impaired immune systems such as cancer and diabetes are at a much greater risk of becoming ill and having more serious illnesses from consuming pathogenic bacteria in milk (Fusco *et al.*, 2020).

Recurrent indiscriminate use of antimicrobial results in development and prevalence of drug resistance pathogens (Muwonge *et al*. 2025). Activities like lack of access to appropriate therapy, unregulated drug supply chains, drug purchase without prescriptions and food animal treatment by unskilled people (Manyi Loh *et al*., 2018) in pastoral animal production due to weak regulatory frameworks (Musuka *et al*., 2025) results in transmission of resistant pathogenic to humans through consumption of contaminated food (Guo *et al*. 2021).

3. MATERIALS AND METHODS

3.1. Descriptions of the study area

The study was conducted in Elwaye, Gomole and Yabelo districts of Borana zone and Fantale district of East Shewa zone of Oromia regional state, Ethiopia (Figure 1). Borana is located at a distance of 570 km south of Addis Ababa and extends to the Kenyan border in the South; Somali region in the South East; South Ethiopia Regional State in the West and North; and Guji zone in the North East. Elwaye, Gomole and Yabelo districts of Borana climate is characterized by a semiarid to arid climate (Haile, 2011). Geographically, the area is located between from 4 to 6° N latitude and from 36 to 42° E longitude with altitude ranging from 1000 to 1700 m above sea level (ASL). The mean annual rainfall of the area ranges from 250 to 700 mm. The annual mean temperature varies from 19 to over 25 °C (Gelagay *et al*. 2007).The rain pattern is of a bimodal type with the main rainy season (ganna) extending from March to May and the small rainy season (hagaya) from September to November. The other two seasons are the cool dry season (adolesa) extending from June to August and the major dry season (bona) extending from December to February (Alemayehu *et al*., 2025).

East Shewa Zone lies between 60 00’ N to 70 35‘N and 380 00’E to 400 00’E and located at 100 km of East Addis Ababa. This zone is bordered on the South by the West Arsi Zone, on the Southwest by the South Ethiopia Regional State, on the West by South West Shewa Zone, on the Northwest by North Shewa, and on the Southeast by Arsi Zone. Fantale district is a sparsely populated lowland pastoral and agro-pastoral area. Rainfall is extremely irregular, with an average annual rainfall of 550.9 mm. The mean minimum and maximum temperatures are 17.4°C and 32.7°C, respectively. The area falls within an altitude range of 862 meters and 1,135m ASL. The topography is predominantly plains (Meseret *et al*., 2024).

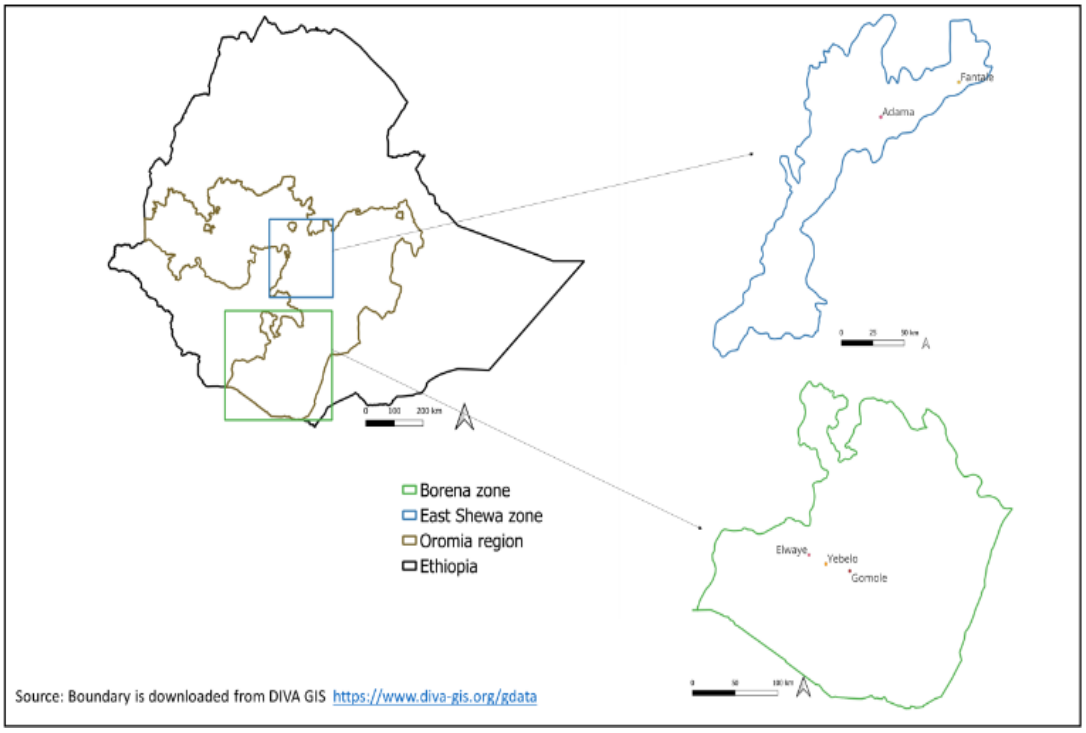


Figure 1: Map of Ethiopia showing the study areas

3.2. Study Subjects and Design

The study subjects include all relevant actors involved in the camel milk value chain in Borana and east shewa zone, which were recruited from camel producers, milk collectors, retailers and others. The camel rearing households were subsampled for assessing milk handling practices and bacteriological quality. In addition, other value chain actors including camel milk collectors, who transport milk from producers to market centers; retailers those operating in local markets and roadside sales and cafeteria operators who prepare and sell raw or processed camel milk products to consumers were also recruited. Camel milk cooperatives were also considered as part of the population due to their role in milk aggregation, handling and distribution. Furthermore, camel milk consumers were included to assess consumption practices and potential public health risks associated with raw milk intake. To complement the field data, experts from governmental and non-governmental organizations working in livestock production, veterinary public health and food safety in the study areas were also included. These experts provided insights into milk hygiene practices, disease risks and existing interventions related to camel milk safety.

A prospective longitudinal study was conducted from March 2025 to March 2026 to collect sample from value chain actors and to assess the bacteriological quality of raw camel milk along its value chain in both wet and dry season from the same participants. The study was integrated both qualitative and quantitative approaches, including: questionnaire survey to assess milk handling practices, hygiene condition, knowledge and practices among camel milk value chain actors alongside with laboratory analysis of samples to determine bacteriological loads of camel milk and swab samples along camel milk value chain actors.

3.3. Sample size determination

From the total households 385 camel herders initially recruited for the SUSCAMI project, 24 camel herds from each of Borana and East Shewa zones (total 48 from the two sites) were randomly selected for seasonal milk sampling. Then three lactating camels were randomly selected from each herd for milk sample collection. These make a total of 144 lactating camels from both study zones. Similarly, a total of 20 collectors, 10 retailers, 10 cafeteria owners and 4 cooperatives were randomly selected for milk sampling and container swab sample collections. In addition to this 20 camel milk consumers and 12 experts were randomly selected for questionnaire survey only (Table 1). A total of 752 samples (472 milk samples, 280 container and hand swab samples) were collected from both east shewa and Borana zone in wet and dry seasons (Table 2). Additionally, questionnaires were administered to 48 producers, 20 milk collectors, 10 retailers, 10 cafeteria, 4 cooperatives, 20 milk consumers and 12 government and non-governmental organization experts which make a total of 124 value chain key informants from both study sites.

Table 1: Distribution of the value chain actors for milk handling practices and samplings

Value chain actors	Borana	East Shewa	Total
Producers	24	24	48
Collectors	10	10	20
Retailers	5	5	10
Cafeteria owners	5	5	10
Cooperatives	2	2	4
Consumers	10	10	20
Livestock experts	6	6	12
Total	**62**	**62**	**124**

Table 2: Distributions of microbial samples by value chain actors and zones for both wet and dry seasons

Value chain actors	Samples	Borana	East Shewa	Total
Producers	Udder milk, individual camel	144	144	288
	Bulk milk, herd	48	48	96
	Hand swab, herder	48	48	96
	Container swab, household	48	48	96
Collectors	Milk, bulk	20	20	40
	Container swab	20	20	40
Retailers	Milk, bulk	10	10	20
	Container swab	10	10	20
Cafeteria owners	Milk, bulk	10	10	20
	Container swab	10	10	20
Cooperatives	Milk, bulk	4	4	8
	Container swab	4	4	8
Total		**376**	**376**	**752**

3.4. **Sampling Technique**

A multistage sampling technique combined with purposive and simple random sampling methods were employed to select study participants and milk samples along the camel milk value chain in Borana and East Shewa zone. In the first stage, districts (woredas) with high camel population and active camel milk production and marketing were purposively selected based on their production potential, accessibility and relevance to the study objectives. In the second stage kebeles within the selected districts were also randomly chosen to represent major camel milk producing areas.

In the third stage, households owning lactating camels were sampled using simple random sampling. This ensured that each household had an equal chance of being included in the study. Where selected household was not available or not cooperative to take part in the study, another household in the category was used to replace. Lactating camels from selected households were sampled by convenience sampling.

For other actors along the value chain, including milk collectors, retailers, cafeteria operators and cooperative members, a purposive sampling technique was used due to their limited number and specific roles in camel milk handling and distribution. Similarly, camel milk consumers were selected using a convenience sampling approach at market and consumption points to capture actual consumption practices. In addition, experts were selected using convenience sampling approach from veterinary related government and non-government organizations.

3.5. Data collection methods

3.5.1. Questionnaire survey

The questionnaire survey was used to collect data on camel handling practices and associated risk factors along the value chain in Borana and East shewa zone. A semi-structured and pretested questionnaire was administered to lactating camel owners, milk collectors, retailers, cafeteria operators, cooperatives and consumers. The questionnaire was designed to include both closed ended and open ended questions, organized into different sections. These sections covered: Socio demographic characteristics, milking and milking handling practices, transportation and storage practices, milk consumption habits and awareness of milk borne diseases.

Survey was conducted on the milking, milk handling practices and hygienic measures along the milk value chain using semi-structured questionnaires. Key principles of good dairy production practices that ensure food safety and nutrition quality of dairy products are considered. Value chain actors‟ knowledge and perception are inquired regarding milk and personal hygiene, camel milk processing and preservation (e.g., smoking containers with plant extracts, boiling) methods to ensure milk hygiene and safety, enhance shelf life of camel milk, and avoid milk spoilage and adulteration. In addition, perception about

(public) health risks of raw and spoiled camel milk consumption, antibiotic treatment of camels and withdrawal period of the milk are assessed in the interviews. In addition, factors that affect microbial quality and safety of camel milk such as animal health, milking environment, personal hygiene of milk handlers, water quality, container hygiene and cleaning practices, conditions of milk storage and transportation are investigated through direct observation of practices (i) before milking (e.g., hand washing, udder preparation, cleaning, disinfection or smoking of milk containers), (ii) during milking (e.g., cleanliness of milking environment, types of containers used for milking), and (iii) after milking (e.g., storage and transportation containers, transportation conditions of milk, exposure to sun, cold storage facilities, refrigeration).

3.5.2. Milk and swap sample collection

Approximately 5-10 ml of raw camel milk was collected into sterile screw capped falcon tube and 9 ml of buffered peptone water was used to collect swab samples. During sampling strict hygienic procedures were followed to avoid external contamination. Each sample was clearly labeled with date, location and source. The samples were immediately placed in an ice box and transported to the laboratory within a few hours of collection. The milk samples are stored at 4 °C until culturing for coliform count and aerobic plate count at the microbiology laboratory of the College of Veterinary Medicine and Agriculture, AAU (samples of East Shewa zone).

Microbial sample culture and count of the samples of Borana zone are performed at the Yabelo regional veterinary laboratory of the Oromia region in Yabelo. Total aerobic plate count (APC) and coliform count (CC) are performed and data were transformed to log values. The microbial quality and safety of camel milk was assessed along the milk value chain, namely at households, milk collection points, retailers, cafeteria and cooperatives.

Aerobic plate count (APC)

The total bacteria count was done using pour plate method. Standard Plate Count Agar was used. This test was carried out to determine the content of microbial contamination of milk before any processing was done. One milliliter (1 ml) of milk and swab samples was serially diluted in 9 ml of peptone water (ratio of 1:10) up to six dilutions. Sterile duplicate

glass petri dishes are labeled according to the dilution index. One ml of the dilutions was aseptically with drawn using a sterile 1 ml Pasteur pipette and was delivered into an opened and sterile petri dish and then closed, the same procedure done for a duplicate petri dish. This was repeated till all the dilutions are pipetted into their corresponding plates up to 10^{-6}. This was followed by pouring about 15 ml of standard plate count agar which had been autoclaved at 121 °C for 15 min, cooled and tempered in a water bath at 50 °C. The sample and the agar are gently mixed by alternate clock and anti-clockwise rotations and left to solidify on the bench for about 30 min. The plates are inverted and incubated at 37 °C for 48 h. After incubation, plates inoculated with sample dilution yielding between 30 and 300 colonies are counted. Colony counts are made using colony counter (Abera et al., 2016).

Coliform count

One ml of milk sample was added into sterile test tube having 9 ml of peptone water. After mixing, the sample was serially diluted up to 1: 10^{-6} and 1 ml of inoculum will be mixed thoroughly with molten 15–20 ml Violet Red Bile Agar solution which was previously held in a water bath at 50 °C. Two plates were inoculated with each dilution. After thoroughly mixing, the plated sample is allowed to solidify and then incubated at 37 °C for 24 hours. Typical dark red colonies are considered as coliform colonies. Finally, colony counts were done using colony counter (Abera et al., 2016).

3.5.3. Quality Control

All laboratory procedures were conducted following standard operating procedures (SOPs). Sterility of media and equipment was ensured. Data were recorded carefully and expressed in log CFU/ml for analysis.

3.6. Data management and analysis

The collected data was entered, cleaned and analyzed using the R software (R version 4.5.2). Data from questionnaires and laboratory results were first organized in Microsoft excel and then imported into R for statistical analysis. Prior to analysis dataset was checked for completeness, consistency and cleaned. Descriptive statistical analysis was performed to summarize the characteristics of the study population and key variables.

Frequencies and percentages were computed to describe socio demographic characteristics, milk handling practices and hygienic conditions along the camel milk value chain in Borana and east shewa zone.

For the analysis of microbial counts such as aerobic plate count (APC) and coliform count (CC) were transformed into logarithmic values (log CFU/ml) to normalize the distribution of the data. Mean bacterial counts were then compared across different sampling points along the value chain (e.g., udder milk, collector milk, retailer milk) to assess variation in contamination levels. Inferential statistical analysis was conducted to identify associations between milk handling practices and bacteriological quality. Multiple logistic regression tests were used to assess associations between categorical variables, such as hygiene practices and contamination status. The level of statistical significance was set at $P < 0.05$ and results were interpreted accordingly.

3.7. Ethical Clearance

This study was granted ethical approval by the College of Veterinary Medicine and Agriculture Animal Research Ethics Committee of Addis Ababa University, with reference number VM/ERC/02/50/17/2025 (Annex 15). All procedures were executed by skilled professionals according to the guidelines and regulations established by the university's ethics committee. The welfare and well-being of the animals that participated in this study were ensured throughout the research. Before the commencement of the study, verbal consents were obtained from all camel milk producers, collectors, retailers, cafeteria owners, cooperatives, consumers and experts for the questionnaire interview, collection of milk and swab samples.

4. RESULTS

4.1. Demographic characteristics of milk value chain actors

Out of 48 camel milk producers 91.7% of them were male and 8.3% of them were female with 85.4% of them aged 30 and above years and 14.6 % of them aged below 30 years. Most of the producers (77.1%) were illiterate, followed by 18.8% elementary education, with few of them (4.2%) having high school and above education. Most of the producers (89.6%) were doing crop production, trading and casual labor as a non-livestock source of income and 10.4% of them were getting income from house rent, charcoal and incense sell as a non-livestock source of income (Table 3).Among the milk collector 80% of them were females and 20% of them were male with 75% of them aged below 30 years and 25% of them aged 30 and above years. Less than half of the collectors (45%) were illiterate, followed by 35% elementary education, with 20% having high school and above education. All the collectors (100%) were selling camel milk as non-livestock source of income of this respondent 90% were married and 10% were single (Table 3).

All of the retailers were female and 70% of them were below 30 years age and 30% of them were 30 years and above. Less than half of the retailers (40%) have elementary school education followed by 30% illiterate, with 30% having high school and above education. Most of the retailers (60%) were married, 40% of them were single. All of the retailers (100%) were doing crop production, trading and selling camel milk as a non-livestock source of income. Out of 10 cafeteria owners 50% were female and 50% of them were male. Most of the cafeteria owners (70%) aged 30 and above years and 30% of them aged below 30 years. Half of the cafeterias (50%) were selling camel milk as a non-livestock source of income (Table 3).

Table 3: Socio-demographic characteristics of value chain actors

Variables	**Levels**	**Producers (n=48)**		**collectors (n=20)**		**Retailers (n=10)**		**Cafeteria** (n=10)	
		n	%	n	%	n	%	n	%
Sex	Male	44	91.7	4	20	0	0	5	50
	Female	4	8.3	16	80	10	100	5	50
Age	below 30	7	14.6	15	75	7	70	3	30
	30 and above	41	85.4	5	5	3	30	7	70
Education	High school & above	2	4.2	4	20	3	30		
	Elementary	9	18.8	7	35	4	40		
	Illiterate	37	77.1	9	45	3	30		
Marital status	Married			18	90	6	60		
	Single			2	10	4	40		
Non-livestock income sources	Crop production, trading and selling milk	43	89.6	20	100	10	100	5	50
	Renting house, selling charcoal and incense	5	10.4						

4.2. Milk consumption practices and food safety risk awareness among value chain actors

Table 4 shows milk consumption, safety perceptions, and practices across four value chain groups. Producers had the highest daily consumption (100%), followed by cafeteria owners (80%), urban consumers (45%), and experts (58.3% “sometimes”, 16.7% “never”). Fresh raw milk was preferred by most producers, 70% of urban consumers, and 60% of cafeteria owners. Raw milk was consumed daily by 97.9% of producers, 70% of cafeteria owners, 45% of urban consumers, and only 8.3% of experts.

Food safety awareness was highest among experts (83.3% aware of zoonoses, 75% of drug residues) and lowest among producers (41.7% and 14.6%, respectively). Most producers (89.6%) and cafeteria owners (70%) had no safety concerns, while 75% of experts expressed concern. Adulteration was acknowledged by 60% of cafeteria owners and consumers, 25% of experts and 20.8% of producers (mainly water addition). Results indicated that boiling milk for vulnerable population groups such as children, pregnant

women, elderly or sick persons was not a common practice (Table 4), particularly among producers and end consumers, despite its potential food safety benefits. Only 14% of producers, 30% of cafeteria owners and 30% consumers practiced boiling for this population at risk sometimes. Similarly, boiling milk for the respondents' own consumption was nearly absent among producers (95.8%) and consumers (90.0%), with cafeteria owners expressing limited practice (rarely, 40%).

Table 4: Milk consumption patterns and food safety risk awareness among value chain actors

Variables	**Levels**	**Producers (n=48)**		**Experts (n=12)**		**Cafeteria (n=10)**		**Consumers** (n=20)	
		n	%	n	%	n	%	n	%
Camel milk consumption	Every day	48	100	2	16.7	2	20	10	50
	Never	0	0	2	16.7	0	0	0	0
	Sometimes	0	0	7	58.3	8	80	9	45
	At least once a month	0	0	1	8.3	0	0	1	5
Main type of milk consumed	Boiled with tea	9	18.8	2	16.7	4	40	4	20
	Fresh raw	36	75	9	75	6	60	14	70
	Fresh boiled	1	2.1	1	8.3	0	0	1	5
	Fermented	2	4.2	0	0	0	0	1	5
Raw milk consumption	Every day	47	97.9	1	8.3	7	70	9	45
	Never	0	0	3	25	0	0	0	0
	Sometimes	1	2.1	7	58.3	3	30	10	50
	At least once a month	0	0	1	8.3	0	0	1	5
Zoonoses awareness	No	28	58.3	2	16.7	6	60	11	55
	Yes	20	41.7	10	83.3	4	40	9	45
Drug residue awareness	No	41	85.4	3	25	6	60	11	55
	Yes	7	14.6	9	75	4	40	9	45
Concern of raw milk safety	No	43	89.6	3	25	7	70	11	55
	Somewhat	1	2.1	4	33.3	2	20	5	25
	Strongly	4	8.3	5	41.7	1	10	4	20
Milk can be adulterated	No	38	79.2	9	75	4	40	8	40
	Yes	10	20.8	3	25	6	60	12	60

Boiling milk for risk group (children, pregnant women & elderly/sick person)	Never	36	75	5	50	6	30
	Rarely	5	10.4	2	20	1	5
	Sometimes	7	14.6	3	30	4	20
	Daily	0	0	0	0	9	45
Boiling milk for yourself	Never	46	95.8	6	60	18	90
	Rarely	2	4.2	4	40	2	10
	Sometimes	0	0	0	0	0	0

4.3. Milking and milk handling practices of producers

Table 5 Presents hygienic milking and milk-handling among camel milk producers in both study areas. Most of the producers (72.9%) never wash their hands before milking, with a higher proportion for producers in East Shewa (20 out of 24) as compared to those in Borana (15 out of 24). Conversely, hand washing after milking was nearly practices by 91.7% of them. Among those who wash their hands, most use only water (25.0%), while soap use is generally very low (6.3%) and reported only in Borana. In contrast, vessel hygiene practices were considerably better as nearly all producers (97.9%) wash their milk containers every day and 95.8% smoke the milk containers daily. However, vessel washing methods varied by zone: Borana producers mainly used only water (18 out of 24), while herders in East Shewa more frequently used water with ash, and herbs (10 out of 24) for washing. Soap use for vessel cleaning was practiced only by few herders in Borana (6.3%). These findings indicate that while container hygiene is prioritized, personal hand hygiene remains a major challenge requiring targeted interventions.

Plastic buckets were used by all East Shewa producers and most in Borana (71%). In Borana, traditional wooden vessels (6.3%) or mixed use (8.3%) were also not uncommon (Table 6). For milk transport and storage, narrow-mouthed plastic containers were nearly universal (97.9–100%), indicating widespread use of unsuitable, non-food grade containers. East Shewa producers used only piped water, while Borana relied on natural, uncovered sources such as ponds, rivers, or springs, posing hygiene risks. Nearly all producers (97.9%) stored milk at room temperature except for few respondents used a cool place (refrigeration). Most producers (70.8%) reaches market within 12 hours, though East Shewa more often stored milk over 12 hours compared to Borana, especially as evening

milk kept overnight. Milk for home consumption was stored for about 24 hours at room temperature and considered safe (89.6%).

Table 5: Milk handling practices, storage and transportation conditions of producers

Milk handling practices	Level	Borana	East Shewa	Total	Percent (%)
Hand washing before milking	Always	5	0	5	10.4
	Sometimes	4	4	8	16.7
	Never	15	20	35	72.9
Hand washing after milking	Always	21	23	44	91.7
	Sometimes	3	1	4	8.3
Hand washing methods	Use water only	10	2	12	25.0
	Use soap & water	3	0	3	6.3
	Use water & ash	1	0	1	2.1
	Don't wash	10	22	32	66.7
Vessel washing	After every milking	1	0	1	2.1
	Every day	23	24	47	97.9
Vessel washing methods	Use water only	18	14	32	66.7
	Use water, ash, herbs	3	10	13	27.1
	Use water & soap	3	0	3	6.3
Smoking frequency	Every day	22	24	46	95.8
	At least two days per week	2	0	2	4.2
Water sources	Pond	16	0	16	33.3
	River	3	0	3	6.3
	Pipe	5	24	29	60.4
Milking vessels	Plastic bucket	17	24	41	85.4
	Wooden vessel	3	0	3	6.3
	Wooden and plastic	4	0	4	8.3
Milk storage condition	Room temperature	24	23	47	97.9
	In a cool place	0	1	1	2.1
Milk storage before marketing	Less than 12 hours	21	13	34	70.8
	Over 12 hours	3	11	14	29.2
Milk storage before utilization	About 24 hours	20	23	43	89.6
	1-3 days	4	1	5	10.4

4.4. Milk hygiene and food safety knowledge and practices of producers

The analysis shows knowledge gaps among producers regarding milk hygiene and food safety risks, with notable variations between Borana and East Shewa. While a majority (62.5%) correctly recognized that unclean areas can cause contamination and that milk from sick camels can cause illness, critical misconceptions were also noted. Most of the producers (91.7%) did not believe that raw milk is more likely to cause illness compared boiled milk a perception shared by all of the Borana producers and 20 out of 24 of those in

East Shewa. Similarly, most producers were unaware of specific risks of milk being contaminated by contact with camel feces or with camel urine. Most of them (85.4%) also did not know that drug residues in milk can cause illness. Awareness of high-risk groups (children, pregnant women, elderly) was also low (50%), and half of the producers lack this knowledge (Table 6).

A considerable proportion of producers (66.7%) recognized that dirty hands during milking affect milk safety, while fewer of them understood specific contamination pathways such as touching calves during milking (27.1%) or touching soil or feces (37.5%) can contaminate milk. Most respondents (64.6%) knew that consuming milk from sick camels or spoiled milk poses health risks, but fewer (41.7%) recognized risks from aborted camels. However, a large proportion (79.2%) believed that milk which looks clean to the eyes is safe, the most prevalent misconception. These findings imply the need for producer trainings addressing specific knowledge gaps and improving hygienic milk handling practices.

Table 6: Producers' knowledge gaps on milk hygiene and food safety

Knowledge of milk hygiene and safety	**Responses**	**Borana**	**East Shewa**	**Total**	**Proportions**
Unclean area causes contamination	No	10	8	18	37.5
	Yes	14	16	30	62.5
Milk from sick camel causes illness	No	10	8	18	37.5
	Yes	14	16	30	62.5
Raw milk causes more illness than boiled	No	24	20	44	91.7
	Yes	0	4	4	8.3
Milk mixed with camel feces causes illness	No	22	18	40	83.3
	Yes	2	6	8	16.7
Milk mixed with camel urine causes illness	No	20	21	41	85.4
	Yes	4	3	7	14.6
Drug residues in milk can cause illness	No	19	22	41	85.4
	Yes	5	2	7	14.6
Children, pregnant women and elderly are at high risk	No	13	11	24	50.0
	Yes	11	13	24	50.0
Dirty hands at milking affect milk safety	No	12	4	16	33.3
	Yes	12	20	32	66.7
Touching /grooming calves at milking contaminates milk	No	18	17	35	72.9
	Yes	6	7	13	27.1
Touching soil/feces contaminates milk	No	13	17	30	62.5
	Yes	11	7	18	37.5

Milk from aborted camels causes illness	No	14	14	28	58.3
	Yes	10	10	20	41.7
Milk from sick camels causes illness	No	10	7	17	35.4
	Yes	14	17	31	64.6
Drinking spoiled milk causes illness	No	10	4	14	29.2
	Yes	14	20	34	70.8
Milk that looks clean is safe	No	2	8	10	20.8
	Yes	22	16	38	79.2

Regarding hygienic practices of producers, the majority (93.8%) did not discard the first squirts of milk during milking, did not boil milk before consumption, and also fail to avoid touching calves during milking (70.8%). Approximately two-thirds continue handling milk when experiencing diarrhea (66.7%) or cough (66.7%), and 60.4% continue to handle milk despite having wounds, indicating a low awareness of the role of personal illness in compromising milk safety (Table 7).

Avoiding touching soil or feces during milking was practiced by 60.4%, and 60.4% also reported avoiding selling or consuming milk from sick camels. However, compliance was lower for practices related to withdrawal period for camels under treatment or post treatment: only 22.9% avoid consuming and 31.3% avoid selling milk from treated camels. There was a high regional difference regarding avoiding adding urine or feces to milk, which was a common practice in East Shewa, mainly on demand due to beliefs of a medicinal benefit (table 7). These findings highlight widespread non-compliance with basic hygienic practices, particularly those related to personal illness, sick animals under treatment, and adding camel urine or feces that increase milk contamination.

Table 7: Hygienic practices of producers related to milk hygiene and food safety

Hygienic practices	Response	Borana	East Shewa	Total	Proportion
Discard first squirt milking	No	23	22	45	93.8
	Yes	1	2	3	6.3
Boil milk before consumption	No	20	24	44	91.7
	Yes	4	0	4	8.3
Avoid touch calf during milking	No	16	18	34	70.8
	Yes	8	6	14	29.2
Avoid handling milk if has diarrhea	No	16	16	32	66.7
	Yes	8	8	16	33.3
Avoid handling milk if has cough	No	17	15	32	66.7
	Yes	7	9	16	33.3
Avoid handling milk if has wound	No	14	15	29	60.4
	Yes	10	9	19	39.6
Avoid touching soil/feces during milking	No	12	7	19	39.6
	Yes	12	17	29	60.4
Avoid consuming milk from treated camel	No	20	17	37	77.1
	Yes	4	7	11	22.9
Avoid selling milk from treated camel	No	19	14	33	68.8
	Yes	5	10	15	31.3
Avoid selling/consuming milk from sick camel	No	11	8	19	39.6
	Yes	13	16	29	60.4
Avoid adding urine/feces to milk	No	4	18	22	45.8
	Yes	20	6	26	54.2

4.5. Conditions of milk vessels, milk storage and transportation by producers, collectors and retailers

The types of milk vessels, storage conditions, and transportation practices utilized by three types of value chain actors are summarized in Table 8. Wide mouthed plastic buckets were predominantly used by producers (85.4%), while few of them still used traditional wooden vessels (6.3%) or a combination of both wooden and plastic vessels (8.3%) for milking. For milk transport from the farm gate or collection point to the market, narrow-mouthed plastic containers were used by almost all actors (97.9–100%), mainly due to their tight screw caps. Storage vessels also showed a similar pattern, with all producers using narrow-mouthed plastic containers. Regarding water sources for cleaning hands and vessels, some value chain actors depended on uncovered water sources such as ponds. Others,

particularly those in East Shewa, used pipe water, indicating the use of unsafe (unclean water) by most actors.

Milk was mostly stored at room temperature (producers 97.9%, collectors 100%, retailers 90%), with only one respondent reporting the use of refrigeration. Transportation conditions also reflected this pattern, with all respondents transporting milk at ambient temperature, and in most cases exposed to sunlight. Milk was often kept for about 12 hours before being marketed (producers 70.8%, collectors 75%, and retailers 70%). Travel time to the market was reported to be about 2 hours. The limited cold chain infrastructure and transporting milk for extended periods poses risks to milk quality and safety.

Table 8: Milk vessels, milk storage and transportation conditions among producers, collectors &retailers

Variable	**Level**	**Producers**		**Collectors**		**Retailers**	
		n	%	n	(%)	n	(%)
Milking vessel	Plastic with wide mouth	41	85.4				
	Wooden	3	6.3				
	Wooden & plastic	4	8.3				
Transporting vessels	Plastic with narrow mouth	47	97.9	20	100	10	100
	Plastic with wide mouth	1	2.1	0	0	0	0
Storage vessels	Plastic with narrow mouth	48	100	0	0		0
Water source	Pond/spring	16	33.3	8	40	7	70
	River	3	6.3	0	0	0	0
	Pipe	29	60.4	12	60	3	30
Milk storage condition	Room temperature	47	97.9	20	100	9	90
	In a cool place	1	2.1	0	0	1	10
Milk transportation condition	Room temperature	47	97.9	20	100	10	100
	In a cool place	1	2.1	0	0	0	0
Milk storage time before marketing	< 12 hours	34	70.8	15	75	7	70
	> 12 hours	14	29.2	5	25	3	30
Travel time to market	< 2 hours	29	60.42	0	0	0	0
	2-4 hours	19	31.25	0	0	0	0

4.6. Camel milk handling practices by other value chain actors (non-producers)

During the study time all the collectors store camel milk at room temperature and all of them use plastic with narrow mouth to transport camel milk to market destinations. Most of the collectors (75%) kept camel milk for less than 12 hours before sell or consumption and 25% kept for 12-24 hours before sell or consumption. All the collectors (100%) clean and smoke the transport vessels every day (Table 9). Nearly all retailers (90%) store camel milk at room temperature and only 10% of them store camel milk in refrigerator. Most of the retailers (70%) were keeping camel milk for less than 12 hours before being sold at the market and 30% of them were keeping camel milk for 12-24 hours before being sold at the market (table 9). Most of the cafeteria owners (70%) were responded as the common source of camel milk contaminations were infected camel, unclean containers and hands. Most of the cafeteria owners (60%) were aware of zoonotic diseases transmitted through camel milk and 40% of them were having no awareness about zoonotic diseases transmitted through camel milk (table 9).

All of the cooperatives were storing camel milk from collection point in their shop at room temperature by using plastic with narrow mouth. Out of 4 cooperative members 50% of them were smoking storage vessels every day and 50 % of them were smoking twice a day. During the study time all of the cooperatives were keeping camel milk for less than 12 hours before further transported to the market (table 9).Most of the consumers (75%) were keeping camel milk at room temperature, followed by 20% in refrigerator and 5% were keeping in cool place. During the study time 70% consumers responded dirty udder, infected camels, unclean containers and hands were the common source of camel milk contamination while 30% responded unclean containers and hands. More than half of the consumers (55%) were aware of zoonotic disease transmitted through came milk and 45% of them were not aware of zoonotic disease transmitted through came milk (table 9).

Table 9: Camel milk handling practices by other value chain actors (non-producers)

Variables	**responses**	**Collectors (n=20)**		**Retailers (n=10)**		**Cafeteria (n=10)**		**Cooperatives (n=4)**		**Consumers (n=20)**	
		n	%	n	%	n	%	n	%	n	%
Storage method of camel milk	Room temperature	20	100	9	90			4	100	15	75
	Refrigerator	0	0	1	10					4	20
	Cool place	0	0							1	5
Type of vessel used	Plastic with narrow mouth	20	100					4	100		
Duration of keeping milk before sale/consumption		15	75	7	70			4	100		
	Less than 12 hours										
	12-24 hours	5	25	3	30						
Frequency of smoking vessels		20	100					2	50		
	Every day										
	Twice a day							2	50		
Frequency of cleaning transport vessels		20	100								
	Every day										
common sources of camel milk contamination	Dirty udder, Infected camels, Unclean containers and hands					3	30			14	70
	infected camel, unclean containers and hands					7	70			6	30
zoonotic diseases awareness	Yes					4	40			11	55
	No					6	60			9	45

4.7. Bacterial quality of camel milk along the value chain

The **a**nalysis of milk samples (n=472) across different value chain actors reveals varying levels of bacterial contamination. Milk samples from producers had a mean aerobic plate count (APC) of 7.43 log10 CFU/ml (95% CI: 7.37–7.48) and a coliform count of 7.11 log10 CFU/ml (7.07–7.15), which is lower than collector, cooperatives and cafeteria samples. Cooperatives exhibited the highest APC among all actors, with a mean of 7.76 log10 CFU/ml (7.50–8.01), alongside a notably high coliform mean of 7.49 log10 CFU/ml (7.05–7.92). Collectors showed an APC of 7.66 log10 CFU/ml (7.57–7.76) and a coliform count of 7.11 log10 CFU/ml (7.04–7.18). Retailers recorded an APC of 7.47 log10 CFU/ml (7.34–7.59) but had the lowest coliform count among all groups, at 6.81 log10 CFU/ml (6.56–7.06). Finally, cafeterias had a high APC of 7.73 log10 CFU/ml (7.60–7.85) and a coliform count of 7.35 log10 CFU/ml (7.23–7.47). Overall, cooperatives and cafeterias demonstrated the highest bacterial loads, while retailers had the lowest coliform contamination, suggesting that contamination levels vary significantly depending on the point in the value chain (table 10).

Table 10: Aerobic plate count and coliform count mean log10 CFU/ml of milk samples (n=472)

VC actors	APC log10cfu		CF log10cfu	
	Mean	95% CI	Mean	95% CI
Producer	7.43	7.37 - 748	7.11	7.07 - 7.15
Cooperative	7.76	7.50 - 8.01	7.49	7.05 – 7.92
Collector	7.66	7.57 - 7.76	7.11	7.04 - 7.18
Retailor	7.47	7.34 - 7.59	6.81	6.56 - 7.06
Cafeteria	7.73	7.60 - 7.85	7.35	7.23 - 7.47

The analysis of swap samples (n=280) across different value chain actors reveals varying levels of bacterial contamination. Swap samples from producers had a mean APC of 7.52 log10 CFU/ml (95% CI: 7.45–7.60) and a coliform count of 7.09 log10 CFU/ml (7.02–7.15), which is lower than collector and cafeteria samples. Collectors exhibited the highest APC among all actors, with a mean of 7.70 log10 CFU/ml (7.61–7.78), conversely, with the lowest coliform mean of 7.08 log10 CFU/ml (6.95–7.22). Cooperatives recorded an

APC of 7.50 log10 CFU/ml (7.25–7.76) and coliform count of 7.09 log10 CFU/ml (6.95–7.23). Retailers recorded the lowest APC of all groups at 7.46 log10 CFU/ml (7.34–7.59) and coliform count of 7.18 log10 CFU/ml (6.56–7.06). Finally, Cafeteria showed an APC of 7.68 log10 CFU/ml (7.52–7.85) with the highest a coliform count of 7.26 log10 CFU/ml (7.18–7.34) among all groups (table 11 and figure 3). Overall, cooperatives and cafeterias demonstrated the highest bacterial loads, while retailers had the lowest coliform contamination, suggesting that contamination levels vary significantly depending on the point in the value chain.

Table 11: Aerobic plate count and coliform count mean log10 CFU/ml of swab samples (n=280)

VC actors	**APC log10cfu**		**CF log10cfu**	
	Mean	**95% CI**	**Mean**	**95% CI**
Producer	7.52	7.45 -7.60	7.09	7.02 - 7.15
Cooperative	7.50	7.25 - 7.76	7.09	6.95 - 7.23
Collector	7.70	7.61 - 7.78	7.08	6.95 - 7.22
Retailor	7.46	7.36 - 7.56	7.18	7.02 - 7.31
Cafeteria	7.68	7.52 - 7.85	7.26	7.18 - 7.34

During the study time bacterial count of milk samples of Borana showed slightly higher mean 7.5 log10 CFU/ml APC as compared to east shewa which is 7.45 log10 CFU/ml. in contrast, east shewa showed slightly higher mean CC 7.15 log10 CFU/ml as compared to Borana mean CC 7.1 log10 CFU/ml. These variations may be due to differences in milk handling practices, hygienic conditions and environmental between the two study areas. Seasonal variation had visible effect on both APC and CC. The wet season recorded the highest mean APC of 7.81 log10 CFU/ml and CC of 7.27 log10 CFU/ml as compared to dry season APC 7.15 log10 CFU/ml and CC 6.97 log10 CFU/ml bacterial load (figure 2). The higher bacterial load during wet season may be due to increased environmental contaminations, contaminated water sources and higher moisture levels.

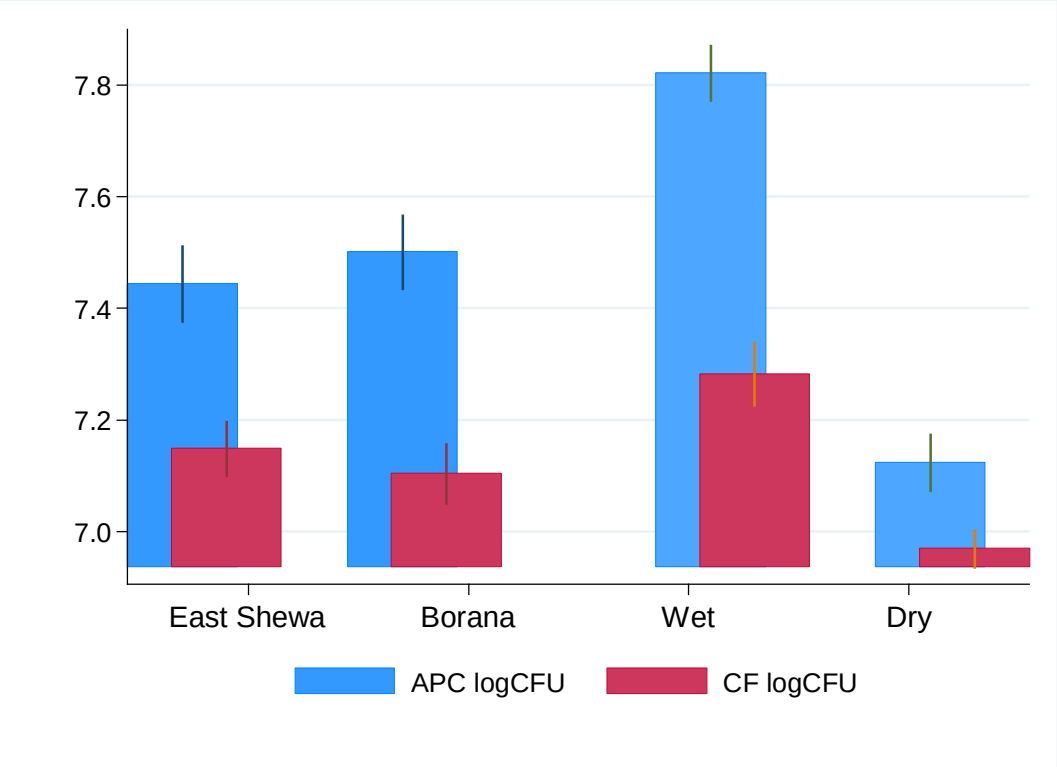


Figure 2: comparison of aerobic plate count and coliform count mean log10 CFU/ml of milk samples (n=472) of two zones and seasons

During the study time bacterial count of swap samples of Borana showed slightly higher mean 7.61 log10 cfu/ml APC as compared to east shewa which is 7.52 log10 cfu/ml. in contrast, east shewa showed slightly higher mean CC 7.15 log10 cfu/ml as compared to Borana mean CC 7.07 log10 cfu /ml. These variations may be due to differences in milk handling practices, hygienic conditions and environmental between the two study areas. Seasonal variation had visible effect on both APC and CC. The wet season recorded the highest mean APC of 7.88 log10 cfu /ml and mean CC of 7.22 log10 cfu /ml as compared to dry season APC 7.24 log10 cfu /ml and CC 7 log10 cfu /ml bacterial load (figure 3). Similar to that of milk samples higher bacterial load during wet season may be due to increased environmental contaminations, contaminated water sources and higher moisture levels.

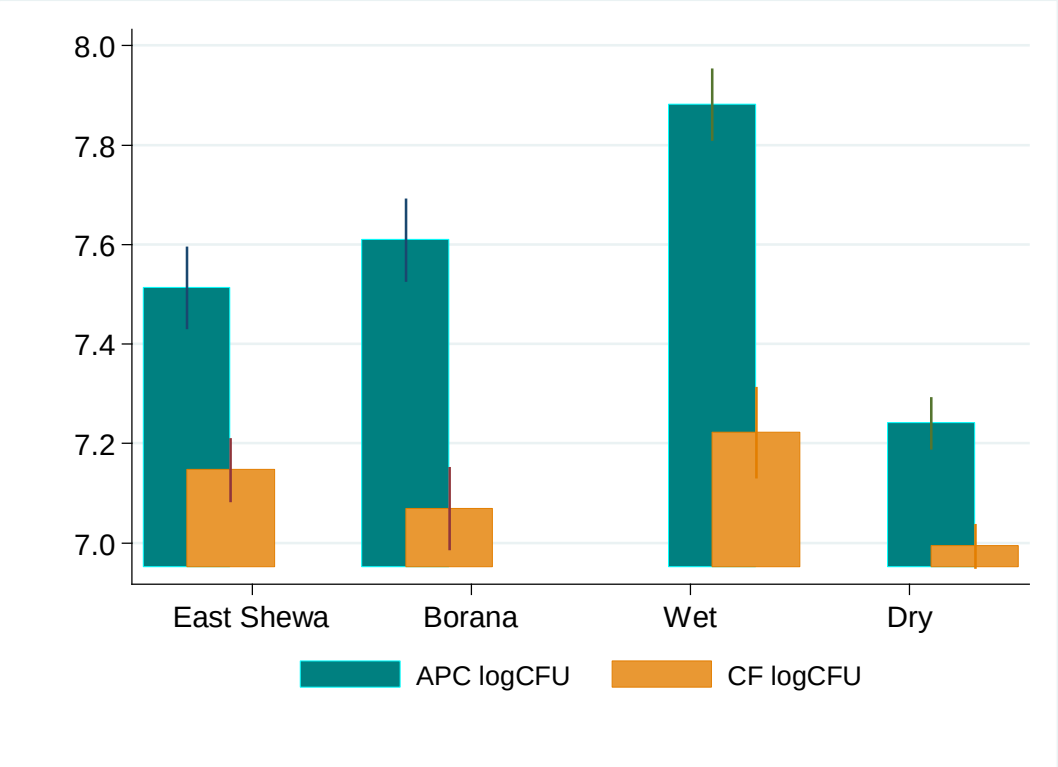


Figure 3: Comparison of aerobic plate count and coliform count mean log10 CFU/ml of swap samples (n=280) of two zones and seasons

Some variables showed significant association with the bacterial loads of the milk samples. In particular, milk samples collected during the wet season shows a substantially higher mean aerobic plate count (APC) of 7.84 log10 cfu/ml compared to 7.17 log10 cfu/ml in the dry season. Vessel washing with soap and water significantly reduces APC compared to using water alone (7.45 vs. 7.57, p=0.010). Notably, higher food safety knowledge and better practices (scores >60%) are both associated with significantly lower APC levels (p=0.022 and p=0.001, respectively). However, while vessel smoking frequency does not significantly associated with APC (p=0.522), it has a strong and highly significant effect on coliform counts; smoking after every use results in a much lower mean coliform count (6.48 log10 cfu/ml) compared to daily or every-two-day smoking (7.13 log10 cfu/ml, coefficient: 0.63, p<0.000) (table 12).

Table 12: Association of variable with bacterial load of milk samples

Variables	Levels	APC log10 cfu/ml of milk samples			Coliform log10 cfu/ml of milk samples		
		mean	Coef	P-value	mean	Coef	P-value
Zone	East Shewa	7.47			7.15		
	Borana	7.54	0.06	0.240	7.09	-0.04	0.221
Season	wet	7.84			7.26		
	dry	7.17	-0.70	0.000	6.98	-0.31	0.000
Sex	male	7.47			7.13		
	female	7.63	0.20	0.001	7.07	-0.07	0.138
Education	none	7.48			7.11		
	elementary	7.60	0.13	0.047	7.12	-0.01	0.877
	high school	7.57	0.04	0.672	7.16	0.06	0.423
Vessel Smoking Frequency	after every use	7.53			6.48		
	daily or every two days	7.50	-0.09	0.522	7.13	0.63	0.000
Vessel Washing	water only	7.57			7.11		
	soap & water	7.45	-0.13	0.010	7.11	0.04	0.314
Food Safety Knowledge	≤ 60%	7.55			7.14		
	> 60%	7.35	-0.15	0.022	7.06	-0.09	0.088
Food Safety Practices	≤ 60%	7.55			7.14		
	> 60%	7.34	-0.22	0.001	7.05	-0.03	0.522

5. DISCUSSION

5.1. Camel milk handling practices and food safety knowledge along value chain actors

The current study showed that majority of camel milk producers lack formal education (77.1%) and 23.1% of them were literate the finding was in line with Igge *et al.*(2020) which says the result of the survey revealed that large proportion of the respondents (97%) did not attended formal education and 3% of them were attended formal education. 91.7% of the camel milk producer were male and 8.3% of them were female these findings is consistent with other studies in similar context (Yosef *et al*., 2025), highlighting predominance of males (67.71%) among those involved in camel milk production in Burao City, Somaliland, suggesting that this industry is primarily driven by men.

Most of the collectors (80%) and all of the retailers (100%) were females. Most collectors (90%) and all of the cooperatives (100%) were married. This finding was similar with the idea of Igge *et al.* (2020) 97.5% of the milk marketer were female whereas 2.5% were male. Regarding the marital status of the respondents 99.5% of them were married, 0.5% was divorced. This result revealed that milk handling and marketing are carried out by women than male in pastoralist's area. In contrast to this report 50% of the cafeteria and 25% of the cooperatives were female. Regarding the marital status only 60% of the retailers were married which is opposing with the reports of Igge *et al.* (2020).

The study revealed that fresh raw milk was preferred by most producers, 70% of urban consumers, and 60% of cafeteria owners. Raw milk was consumed daily by 97.9% of producers, 70% of cafeteria owners, 45% of urban consumers, and only 8.3% of experts. This study's findings concur with those of other studies Bekele *et al*. (2021), which found that most camel-rearing societies consume fresh camel milk. The research by Amenu *et al*. (2019) also showed that raw milk drinking is widespread among pastoral communities in the Borana Zones.

Food safety awareness was highest among experts (83.3% aware of zoonoses, 75% of drug residues) and lowest among producers (41.7% and 14.6%, respectively). Most producers (89.6%) and cafeteria owners (70%) had no safety concerns, while 75% of experts

expressed concern. Adulteration was acknowledged by 60% of cafeteria owners and consumers, 25% of experts and 20.8% of producers (mainly water addition). The report is similar with report of Bekele *et al*., (2021) according to camel milk collectors, traders and key informants, adulteration and lack of cooling facilities are the major problems of milk quality at milk supply of the study area. Milk and milk products are very susceptible to adulteration with water.

Results indicated that boiling milk for vulnerable population groups such as children, pregnant women, elderly or sick persons was not a common practice, particularly among producers and end consumers, despite its potential food safety benefits. Only 14% of producers, 30% of cafeteria owners and 30% consumers practiced boiling for this population at risk sometimes. Similarly, boiling milk for the respondents' own consumption was nearly absent among producers (95.8%) and consumers (90.0%), with cafeteria owners expressing limited practice (rarely, 40%). The report by Bekele *et al*., (2021) indicated that almost all producers in Borana area use raw milk for home consumption. The majority (80.30%) of respondents did not boil milk before consumption. Gebremichael *et al*. (2019) also reported raw camel milk consumption trends in pastoral areas of Afar.

The prevalence of poor hygienic practice, particularly hand washing (73% of camel milk producers do not wash their hands before milking camels and 10% of them wash their hands always before milking camels) and udder cleaning (95.8% never clean udder before milking) raises significant food safety concerns these finding agree with Abubaker *et al*. (2026) highlighting Camel herders engaged in camel milking were not practicing udder washing before milking (100%), 72.5% uses poor quality water for cleaning and 80% did not practice hand washing before and in between milking. All of the camel milk producers (100%) were using plastic with narrow mouth to store camel milk at home and this may compromise milk quality. Plastic buckets were the most commonly used milking vessels (85.4%) among East Shewa and Borana producers this finding agree with Yosef *et al*. (2025) which says the prevalent use of plastic containers (96.48%) instead of more hygienic options, such as stainless steel, suggests cultural practices and economic constraints.

The study revealed that vessel hygiene practices were considerably better as nearly all producers (97.9%) wash their milk containers every day and 95.8% smoke the milk containers daily to give good aroma and enhance the shelf life of milk the present report was similar with reports of Amenu and Amdihun, (2025) who reported that the main reasons for smoking were to increase shelf life of products, improve the aroma and quality of milk. The report by Ebrahim, (2025) indicated that 54.29% of milk supplying pastoralist use only pipe water for cleaning milk vessels. Which is close to current study finding of total producers 60.4% of them were using pipe water for cleaning milking vessels and 39.6% of them were using pond and river water for cleaning milking vessels.

The study revealed that knowledge gaps among producers regarding milk hygiene and food safety risks, with notable variations between Borana and East Shewa. While a majority (62.5%) correctly recognized that unclean areas can cause contamination and that milk from sick camels can cause illness, critical misconceptions were also noted. Similarly, most producers were unaware of specific risks of milk being contaminated by contact with camel feces or with camel urine. Lamuka *et al*. (2017) reported Camel health and contaminated milk were challenging for product consumers health assurance due to the risk of zoonotic pathogens and other food safety issues.

Fewer proportion of producers understood specific contamination pathways such as touching calves during milking (27.1%) or touching soil or feces (37.5%) can contaminate milk. Most respondents (64.6%) knew that consuming milk from sick camels or spoiled milk poses health risks, but fewer (41.7%) recognized risks from aborted camels. However, a large proportion (79.2%) believed that milk which looks clean to the eyes is safe, the most prevalent misconception. These findings imply the need for producer trainings addressing specific knowledge gaps and improving hygienic milk handling practices. Reports by Yosef *et al*. (2025) highlights significant knowledge and training deficits among camel milk producers. Only 12.5% had received hygiene training, and 44.01% were aware of the health risks associated with contaminated milk. Low training and awareness rates have profound implications for food safety. The lack of knowledge likely contributes to the poor hygiene practices observed, such as the low rates of hand washing and udder cleaning. This may be due to inadequate hand and udder cleaning during dairy farming.

Regarding hygienic practices of producers, the majority (93.8%) did not discard the first squirts of milk during milking, did not boil milk before consumption, and also fail to avoid touching calves during milking (70.8%). Approximately two-thirds continue handling milk when experiencing diarrhea (66.7%) or cough (66.7%), and 60.4% continue to handle milk despite having wounds, indicating a low awareness of the role of personal illness in compromising milk safety. Yosef *et al*. (2025) reported prevalence of poor hygiene practices raises significant food safety concerns.

During study time wide mouthed plastic buckets were predominantly used by producers (85.4%), while few of them still used traditional wooden vessels (6.3%) or a combination of both wooden and plastic vessels (8.3%). For milk transport from the farm gate or collection point to the market, narrow-mouthed plastic containers were used by almost all actors (97.9%–100%), mainly due to their tight screw caps. Storage vessels also showed a similar pattern, with all producers using narrow-mouthed plastic containers. Bekele *et al*. (2021) reported that pastoralists and agro pastoralists in the study area used different milking vessels. Accordingly, 79%, 29%, 21% and 3% of respondents used wood, gorfa, plastic, and okole, respectively for milk vessels. In addition, pastoralists and agro-pastoralists also used plastic with narrow mouth (89.4%) and sororo (10.6%) vessels for shipping milk to market.

Regarding water sources for cleaning hands and vessels, some value chain actors depended on uncovered water sources such as ponds. Indicating the use of unsafe (unclean water) by most actors. This finding agrees with Bereda *et al.(2013)* who reported majority (64.4%) of respondent in Ezha district, Ethiopia were using water from non-tap sources for hygienic practices. The report by Bekele *et al*. (2021) stated that in the study area the majority of pastoralists and agro pastoralists (72.73%) use pond water while, 12.88% and 14.39% used bore holes and tap water, respectively for camel dairying activities.

Milk was mostly stored at room temperature (producers 97.9%, collectors 100%, retailers 90%), with only one respondent reporting the use of refrigeration. Transportation conditions also reflected this pattern, with all respondents transporting milk at ambient temperature, and in most cases exposed to sunlight. These findings align with Abubaker *et al.* (2026), which found that 100% of the collection centers and milk sellers did not use

cooling facilities for storage of milk. Similarly, Mohammed, (2025) reported 29.38%, 55% and 3.74% of the camel owners were stored camel milk at room temperature, cool place and refrigerator respectively.

During the study time all the collectors and cooperative (100%), nearly all retailers (90%) and most of the consumers (75%) store camel milk at room temperature. 20% of the consumers and 10% of the retailers were keeping camel milk in refrigerator and 5% of the were keeping camel milk in cool place. This finding is in contrast with the finding of Yosef *et al*. (2025) which indicated that 75.78% of the milk handlers promptly refrigerated the milk; a considerable portion (24.22%) kept it at ambient temperature. Gebremichael *et al*. (2019) also reported 18.3%. 58.5% and 23.2% of camel milk marketing at camel herders' farm gate, along main road-sides and nearest towns without cooling at the local temperature by community, respectively.

During the study time all the collectors and cooperatives were using plastic with narrow mouth to transport camel milk to market destinations. All cooperatives, 75% collectors and 70% retailers kept camel milk for less than 12 hours before sell or consumption while 30% of retailers and 25% collectors kept for 12-24 hours before sell or consumption. Abubaker *et al*. (2026) reported, Most of the collectors (80%) use plastic containers and throughout the value chain, handling of milk up to 12 hours without cooling were observed in the studied area.

Most of the cafeteria owners and consumers (70%) were responded as the common source of camel milk contaminations were infected camel, unclean containers and hands while 30% of responded unclean containers and hands which have the risk of milk-borne disease. Hassen *et al*. (2022) reported unclean udder due to lack of washing the udder before milking, unclean hands, poor personal hygiene and health status, unclean milking containers due to lack of clean water and unclean milking sites are more likely to cause milk-borne diseases.

Most of the cafeteria owners (60%) and 55% of consumers were aware of zoonotic diseases transmitted through camel milk where as 45% of consumers and 40% of cafeteria owners were having no awareness about zoonotic diseases transmitted through camel milk.

All the collectors (100%) clean and smoke the transport vessels every day. Out of 4 cooperative members 50% of them were smoking storage vessels every day and 50 % of them were smoking twice a day. This can lower bacterial contamination of the milk vessels. Gemechu *et al*. (2023) also reported 69.38 percent of respondents practiced smoking storage and milking vessels before milking. Reports of Seifu (2007) and Wanjala *et al*. (2016) indicated that smoking of milk handling containers was effective in hindering microbial growth and could be used as a technique in the sanitation and preservation of raw camel milk in arid and semi-arid areas where cold chains for preservation of milk were unavailable.

5.2. Bacterial loads of camel milk and swab samples along the camel milk value chain

The current study showed that both the milk and swap samples showed varying level of contamination depending on the point in the value chain with Cooperatives exhibited the highest APC among all actors, with a mean of 7.76 log10 CFU/ml, alongside a notably high coliform mean of 7.49 log10 CFU/ml and lowest of retailers recorded an APC of 7.47 log10 CFU/ml and coliform count of 6.81 log10 CFU/ml for milk samples. For swap samples collectors exhibited the highest APC among all actors, with a mean of 7.70 log10 CFU/ml, conversely, with the lowest coliform mean of 7.08 log10 CFU/ml and retailers recorded the lowest APC of all groups at 7.46 log10 CFU/ml and coliform count of 7.18 log10 CFU/ml. The mean raw camel milk and swap sample APC and CC value higher than those reported by Abera *et al*. (2016) which highlights the overall mean APC and CC of raw camel milk samples was 4.75 ± 0.17 and 4.03 ± 0.26 log CFU/ml respectively. The APC of milk and swap samples were in agreement with raw milk samples APC of Qassim region of Saudi Arabia which reported El-Ziney and Al-Turki, (2007) highlighting the mean APC of collected samples was 5 log CFU/ml with a maximum of 7.15 log CFU/ml.

Milk samples from producers had a mean APC of 7.43 log10 CFU/ml which is lower than collector, cooperatives and cafeteria samples. Omer and Dol, (2022) reported the overall mean value of aerobic plate counts of milk samples obtained from producers was lower than of the milk samples obtained from milk collection centers in the Gursum district. The total bacterial count determined from the milk samples was 7.43 log10 CFU/ml and 7.53 log10CFU/ml, for household and milk collection centers, respectively. Similarly on the current study, Swap samples from producers had an APC of 7.52 log10 CFU/ml which is

lower than collector (7.70 log10 CFU/ml) and cafeteria (7.68 log10 CFU/ml) samples. Ebrahim, (2025) reported the overall average aerobic plate count (APC) was 5.37 log10 CFU/ml and 5.80 log10 CFU/ml for milk samples collected from the udder and market chains, respectively. Accordingly, the count increased by 0.43 log10 CFU/ml from udder to market chains. Younan *et al*. (2004) reported APC of Somali camel milk collected from production farms were 7.43 log10 cfu/mL and lower than a primary collection site (8.84 log10 cfu/ mL), a local market (8.83 log10 cfu mL/1) and a distance market (9.23 log10 cfu mL/1).

The current mean APC and CC was greater than the range of Kenyan acceptable limits for raw camel milk intended for direct human consumption and processing which is $\leq 2.0 \times 10^5$ CFU/mL to $\leq 1.0 \times 10^6$ CFU/mL for APC and ≤ 1,000 CFU/Ml to $> 5\times 10^4$ to 1×10^5 CFU/mL for CC (Kenya Bureau of Standards, 2007). This might be due to the differences in initial contamination originating from the udder surface, quality of water used for cleaning milking utensils and the time lapse from production to marketing. Milk collected directly from udder and milking bucket was found with relatively better bacteriological quality than the milk collected from market. This might be due to the traditional methods of distribution and transportation of milk including; use of easily contaminated and hard to clean container, long transit time to markets with frequent opening of containers for retail or milk transfer.

The study revealed that some variables showed significant association with the bacterial loads of the milk samples. In particular, Vessel washing with soap and water significantly reduces APC compared to using water alone (7.45 vs. 7.57, p=0.010). Using the water alone increases the bacterial count. Which was in agreement the report of Chambers, (2005) highlighting aerobic plate counts in raw milk mainly reflect the poor hygienic condition under which the milk was handled at storage temperature and time elapsed since milking. Notably, higher food safety knowledge and better practices (scores >60%) are both associated with significantly lower APC levels (p=0.022 and p=0.001, respectively) this finding was in line the report of Mohammed, (2025) By adopting better hygiene practices, improving storage and transportation conditions, and providing education on proper handling techniques, the safety and quality of camel milk can significantly enhanced.

6. CONCLUSION AND RECOMMENDATIONS

This study was conducted to assess milk handling practices and bacteriological quality of camel milk along the milk value chain in Borana and East Shewa. The result obtained in this study concluded that camel milk produced and marketed along the value chain was exposed to multiple contaminations risks due to poor hygienic handling practices, lack of cold chain infrastructure and limited awareness of food safety at different levels of the value chain. The **a**nalysis of milk and swap samples across different value chain actors starting from milk producers to milk retailers and cafeteria shows varying levels of APC and CC. The milk samples have a high bacterial load which is more than the acceptable limit of Kenya according to Kenyan bureau of standards, indicating poor bacteriological quality and possible health risks to consumers.

Bacterial count of milk and swap samples of Borana showed slightly higher mean APC as compared to east shewa. In contrast, east shewa showed slightly higher mean CC as compared to Borana. The wet season recorded the highest mean APC and CC as compared to dry season APC and CC bacterial load. Some variables showed significant association with the bacterial loads of the milk samples. In particular, milk samples collected during the wet season shows a substantially higher mean aerobic plate count compared to dry season. Vessel washing with soap and water significantly reduces APC compared to using water alone. Notably, higher food safety knowledge and better practices (scores >60%) are both associated with significantly lower APC levels. vessel smoking frequency has a strong and highly significant effect on coliform counts.

Therefore, based on the above conclusion the following recommendations are forwarded:

- ✓ Giving awareness on improved milk handling practices and infrastructure development.
- ✓ Regular washing and sterilization of milk equipment, milkers' hand, udders before and after milking
- ✓ Boiling of milk before collection and distribution for consumption.
- ✓ Provision of clean water for washing hands and milk equipment's.

7. REFERENCES

Abbas, S., Ashraf, H., Nazir, A. and Sarfraz, L. (2013): Physico-chemical analysis and composition of camel milk. *International Research*, ***2***(2), pp.85-98.

Abdurahman, O. (2006): Udder health and milk quality among camels in the Errer valley of eastern Ethiopia. *Livestock Research for Rural Development*, ***18***(8), pp.32-38.

Abera, T., Legesse, Y., Mummed, B. and Urga, B. (2016): Bacteriological quality of raw camel milk along the market value chain in Fafen zone, Ethiopian Somali regional state. *BMC Research Notes*, ***9***, pp.1-6.

Abubaker, A.A., Hiko, A., Teresa, T., Abraha, B. and Waktole, H. (2026): Handling practices, prevalence and antimicrobial resistance profiles of Staphylococcus aureus along the camel milk value chain in Moyale, Oromia Regional State, Ethiopia. *Journal of Food Safety and Risk.*

Abubaker, E.A. and Wedda, M.A.A. (2019): Bacterial quality and somatic cell count (SCC) of camel's milk in port-sudan city in red sea state, Sudan. *World Journal of Pharmacy and Pharmaceutical Science*, ***8***(11), pp.1381-1388.

Adugna, M., Seifu, E., Kebeded, A. and Doluschitz, R. (2013): Quality and safety of camel milk along the value chain in Eastern Ethiopia. *International Journal of Food Studies*, ***2***(2). pp. 150–157.

Ahmed, A.D., Hiko, A., Belina, D., Gebremeskel, H.F. and Kebede, I.A. (2024): Identification and antimicrobial susceptibility profiles of Staphylococcus species isolated from raw cow milk, and swabs in smallholder dairy farms in Meta district, Eastern Ethiopia. *BMC Microbiology*, ***24***(1), p.284.

Ahmed, M. M. (2003): Economic and nutritional impacts of market oriented dairy production in the Ethiopian highlands (Vol. 51). ILRI (aka ILCA and ILRAD)

Alemayehu, S., Olago, D., Alfred, O., Zeleke, T.T. and Dejene, S.W. (2025): Spatiotemporal analysis of rainfall and temperature variability and trends for a mixed crop-livestock production system: its implications for developing adaptation strategies. *International Journal of Climate Change Strategies and Management*, ***17***(1), pp.270-292.

Ali, A., Al-sobayil, F.A., Tharwat, M., Al-Hawas, A. and Ahmed, A.F. (2010): Causes of infertility in female camels (Camelus dromedarius) in middle of Saudi Arabia. *J Agric Vet Sci*, ***2***(2), pp.59-68.

Amenu, K. and Amdihun, K. (2025): Traditional Milk Processing in Borana Pastoral Area, Southern Ethiopia: Practices, Food Safety, Nutrition, and Future Pathways. *Food Science and Nutrition Cases*, (2025).

Amenu, K., Wieland, B., Szonyi, B. and Grace, D. (2019): Milk handling practices and consumption behavior among Borana pastoralists in southern Ethiopia. *Journal of Health, Population and Nutrition*, ***38***(1), p.6.

Amenu, K., Wieland, B., Szonyi, B. and Grace, D. (2019): Milk handling practices and consumption behavior among Borana pastoralists in southern Ethiopia. *Journal of Health, Population and Nutrition*, ***38***(1), p.6.

Bekele, B., Eshetu, M., Wolkero, T., Berhe, T., Galmessa, U. and Gadissa, S. (2025): Hygienic Practices and Determination of Microbial Quality and Safety of Raw Camel Milk in Borana Zone, Southern Ethiopia. *Journal of Food Quality*, *2025*(1), p.2486717.

Bekele, B., Oneta, A., Kumbe, A. and Husein, B. (2021): Indigenous knowledge on camel milk and camel milk products hygienic handling, processing and utilization in Borana Area, Southern Ethiopia. *Journal of Food Science and Nutrition Therapy*, ***7***(1), pp.025-032.

Benta D and Habtamu T. (2011): Study on prevalence of mastitis and its associated risk factors in lactating dairy cows in Batu and its environments, Ethiopia. Global Veterinaria journal***, 7****(6), pp. 632–637****.***

Bereda, A., Yilma, Z. and Nurfeta, A. (2013): Handling, processing and utilization of milk and milk products in Ezha district of the Gurage zone, Southern Ethiopia. *Journal of Agricultural Biotechnology and Sustainable Development*, ***5***(6), p.91.

Chambers, J.V., (2005): The microbiology of raw milk. *Dairy microbiology handbook*, pp.39-89.

Cheesbrough, M. (2000): "Medical Laboratory Manual for Tropical Countries," Microbiology, Linacre House, Jordan Hill Oxford p. 260.

De Buyser, M.L., Dufour, B., Maire, M. and Lafarge, V. (2001): Implication of milk and milk products in food-borne diseases in France and in different industrialised countries. *International journal of food microbiology*, ***67***(1-2), pp.1-17.

Dejene, T.G. (2015): Husbandry practices and utilization of camel products in Borana Zone of Southern Oromia, Ethiopia. *Science Research*, ***3***(4), pp.191-197.

Ebrahim, O.A. (2025): Microbial quality of camel milk along the market value chain in Awsa zone of Afar region, northeast Ethiopia: One health approach. *Daagu International Journal of Basic and Applied research (DIJBAR)*, ***7***(2), pp.737-750.

EL-Fakharany, E., Nawal, A., Bakry, M., Lourdes, S., Nezar, A. and Elrashdy, M. (2012): "Anti-infectivity of camel polyclonal antibodies against hepatitis C virus in Huh7.5 hepatoma," Virology Journal., **201**: 1-9.

Elhadi, Y.A., Nyariki, D.M. and Wasonga, O.V. (2015): Role of camel milk in pastoral livelihoods in Kenya: contribution to household diet and income. *Pastoralism*, ***5***(1), p.8.

El-Ziney, M.G. and Al-Turki, A.I. (2007): Microbiological quality and safety assessment of camel milk (Camelus dromedaries) in Saudi Arabia (Qassim region). *Applied ecology and environmental research*, ***5***(2), pp.115-122.

FAO. (2011): World Livestock in food security. Rome.

FAO. (2020): World Food and Agriculture - Statistical Yearbook 2020. In World Food and Agriculture - Statistical Yearbook 2020. FAO.

Farah, Z., Mollet, M., Younan, M. and Dahir, R. (2007) Camel dairy in Somalia: Limiting factors and development potential. *Livestock Science*, ***110***(1-2), pp.187-191.

Faye, B. (2020): How many large camelids in the world A synthetic analysis of the world camel demographic changes. *Pastoralism*, ***10***(1), p.25.

Fox, P. (2003): Milk. In: Roginski H, Fuquary JW and Fox PF, editors. Encyclopedia of dairy sciences. Vol. **3**. New York: Academic press. p 1805

Fusco, V., Chieffi, D., Fanelli, F., Logrieco, A.F., Cho, G.S., Kabisch, J., Böhnlein, C. and Franz, C.M. (2020): Microbial quality and safety of milk and milk products in the 21st century. *Comprehensive Reviews in Food Science and Food Safety*, ***19***(4), pp.2013-2049.

Gebremichael, B., Girmay, S. and Gebru, M.U. (2019): Camel milk production and marketing: Pastoral areas of Afar, Ethiopia. *Pastoralism*, ***9***(1), p.16.

Gelagay, A., Teshale, S., Amsalu, W. and Esayas, G. (2007): Prevalence of contagious caprine pleuropneumonia in the Borana pastoral areas of Ethiopia. *Small Ruminant Research*, ***70***(2-3), pp.131-135.

Gemechu, A., Gumi, B., Girma, S., Ayana, Z. and Goshu, G. (2023): Camel Milk Handling, Processing, and Utilization in Selected Districts of Borena, East Guji,

and West Guji Zone. *Journal of Agriculture and Veterinary Science*, ***16***(1), pp.1-13.

Guliye A, Noor I and Bebe B. (2007): Role of camels (Camelus dromedarius) in the traditional lifestyle of Somali pastoralists in northern Kenya. Outlook Agric **36**, 29–34.

Guo, K., Zhao, Y., Cui, L., Cao, Z., Zhang, F., Wang, X., Feng, J. and Dai, M. (2021): The influencing factors of bacterial resistance related to livestock farm: sources and mechanisms. *Frontiers in Animal Science*, ***2***, p.650347.

Haile, A. (2011): *Breeding strategy to improve Ethiopian Boran cattle for meat and milk production* (Vol. **26**). ILRI (aka ILCA and ILRAD).

Hassen, M., Amentie, T., Abdimahad, K., Ma'alin, A. and Mahamed, A. (2022): Hygienic production and post-harvest handling practices of raw camel milk in Degahbour district of Jarar zone, Somali Regional State, Ethiopia. *Open Journal of Animal Sciences*, ***12***(2), pp.303-316.

Igge, Ayanle., Mohammed, Abdulkarim., Mahamud, Ahmed and Bhattacharjee, P.S. (2020): Assessment of Camel Milk Marketing Chain and Its Practices in Somali Regional State, Ethiopia. *IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)*, ***13***(7), pp.1-19.

Kaindi, D. W. M., Schelling, E., Wangoh, J., Imungi, J. K., Farah, Z. and Meile, L. (2011). Microbiological Quality of Raw Camel Milk across the Kenyan Market Chain. Food Global Science Books, Food **5** (Special Issue 1), 79-83. Global Science Books.

Kamal Z, Kamal Z, and Heydar N. (2010): Total bacterial, coliforms and the Staphylococcus aureus bacteria count of raw milk (from farms to the processing factory), and pasteurized milk in khozestan province. The 4th Congress on Animal Science, Iran.

Kamana, O., Ceuppens, S., Jacxsens, L., Kimonyo, A. and Uyttendaele, M. (2014): Microbiological quality and safety assessment of the Rwandan milk and dairy chain. *Journal of Food Protection*, ***77***(2), pp.299-307.

Kebede, S., Animut, G. and Zemedu, L. (2015): The contribution of camel milk to pastoralist livelihoods in Ethiopia.

KEBS. (2007): Kenyan Standards for Raw Whole Camel Milk, REF Number KS 2061, Kenya Bureau of Standards

Khasmi, M., Riad, F., Safwate, A., Hidane, K., Faye, B., Davicco, M., Coxam, V. and Barlet,J. (2001): Postpartum evolution of mammary secretion of minerals and 25-Hydroxy vitamin-D in lactating camels (Camelus dromedarius). *Journal of Camel Practice and Research*, **8**(2): 131-135.

Konuspayeva, G., Faye, B., and Loiseau, G. (2009): The composition of camel milk: a meta-analysis of the literature data. *Journal of Food Composition and Analysis*, **22**: 95- 101.

Lamuka, P.O., Njeruh, F.M., Gitao, G.C. and Abey, K.A. (2017): Camel health management and pastoralists' knowledge and information on zoonoses and food safety risks in Isiolo County, Kenya. *Pastoralism*, ***7***(1), p.20.

Mahmoud, H. (2010): Livestock trade in the Kenyan, Somali and Ethiopian borderlands. London: Chatham House/Royal Institute of International Affairs.

Mal, G. and Pathak, K. (2010): Camel milk and milk products. *Report by National Research Centre on Camel*.

Mal, G., Suchitra, S. and Sahani, M. (2007): Changes in chemical and macro-minerals content of dromedary milk during lactation. *Journal of Camel Practice and Research*, **14**(2):195-197.

Manyi-Loh, C., Mamphweli, S., Meyer, E. and Okoh, A. (2018): Antibiotic use in agriculture and its consequential resistance in environmental sources: potential public health implications. *Molecules*., **23**(4), 795.

Megersa, B., Temesgen, W., Amenu, K., Asfaw, W., Gizaw, S., Yussuf, B. and Knight-Jones, T.J. (2024): Camels in Ethiopia: An overview of demography, productivity, socio-economic value and diseases. ILRI Research Report No. 121. Nairobi, Kenya: International Livestock Research Institute (ILRI).

Meseret, T., Dawit, A. and Nabi, H. (2024): Analysis of Land use land cover change and Trend in Fantale Range land, East Shewa zone, Oromia Regional state, Ethiopia. In *Regional Review Workshop on Completed Research Activities* (p. 429).

Mirkena, T., Walelign, E., Tewolde, N., Gari, G., Abebe, G. and Newman, S. (2018): Camel production systems in Ethiopia: a review of literature with notes on MERS-CoV risk factors. *Pastoralism*, ***8***(1), p.30.

Mohammed, J.Y. (2025): assessment of traditional handling, preservation, and processing practices of camel milk and milk products in aba'ala district, afar, Ethiopia.

Musinga, M., Kimenye, D. and Kivolonzi, P. (2008): The camel milk industry in Kenya. *Results of a study commissioned by SNV to explore the potential of Camel Milk from Isiolo District to access sustainable formal markets*.

Musuka, G., Machakwa, J., Mano, O., Iradukunda, P.G., Gashema, P., Moyo, E., Nsengimana, A., Manhokwe, S., Dhliwayo, T. and Dzinamarira, T. (2025): Antimicrobial resistance and its impact on food safety determinants along the beef value chain in Sub-Saharan Africa—A scoping review. *Tropical Medicine and Infectious Disease*, ***10***(3), p.82.

Muthukumaran, M.S., Mudgil, P., Baba, W.N., Ayoub, M.A. and Maqsood, S. (2023): A comprehensive review on health benefits, nutritional composition and processed products of camel milk. *Food Reviews International*, ***39***(6), pp.3080-3116.

Muwonge, K.M., Ndagire, H., Mulindwa, J. and Twesigye, C.K. (2025): Multiple antimicrobial resistance indices of Staphylococcus aureus from the nares of goats and slaughterhouse attendants in Kampala city, Uganda–a cross sectional study. *BMC Microbiology*, ***25***(1), p.162.

Noor, I., Guliye, A., Tariq, M. and Bebe, B. (2013): Assessment of camel and camel milk marketing practices in an emerging peri-urban production system in Isiolo County, Kenya. *Pastoralism: Research, Policy and Practice*, ***3***, pp.1-8.

Oliver, S.P., Jayarao, B.M. and Almeida, R.A. (2005): Foodborne pathogens in milk and the dairy farm environment: food safety and public health implications. *Foodborne Pathogens and Disease*, ***2***(2), pp.115-129.

Omer, A. and Ateye, M., (2023): Assessment of Market and Marketing System of Raw Camel Milk in Gursum District, Somali Regional State, Ethiopia. *Asian Journal of Advances in Research*, pp.484-491.

Omer, A.G. and Dol Ateye, M. (2022): Analysis of physical and microbiological quality of raw camel milk in the Somali regional state of Ethiopia. *Online Journal of Animal Feed Researc*, ***12***(6), pp.372-378.

Onjoro, P., Schwartz, H., Njoka, E. and Ottaro, J. (2003): Effects of mineral status in the soil, forage, water, blood, milk, urine and faeces on milk production of lactating, free ranging camels in Northern Kenya. In: *Proceedings of the Deutscher Tropentag 2003*, Gottingen, Germany, 8–10 October 2003.

Owusu-Kwarteng, J., Akabanda, F., Agyei, D. and Jespersen, L. (2020): Microbial safety of milk production and fermented dairy products in Africa. *Microorganisms*, ***8***(5), p.752.

Panwar, R., Grover, C.., Kumar, V., Ranga, S. and Kumar, N. (2015): Camel milk: Natural medicine-Boon to dairy industry. *Dairy Foods*.

Park, Y., Haenlein, G. and Wendorff, W. (2006): *Handbook of milk of non-bovine mammals* (pp. 34-58). London: Blackwell.

Rahmeh, R., Alomirah, H., Akbar, A. and Sidhu, J. (2019): Composition and properties of camel milk. Milk production, processing and marketing book.

Seifu, E. (2007): Handling, preservation and utilization of camel milk and camel milk products in Shinile and Jijiga Zones, eastern Ethiopia. *Livestock Research for Rural Development*, ***19***(6), pp.1-16.

Semereab, T. and Molla, B. (2001): Bacteriological quality of raw milk of camel (Camelus dromedarius) in Afar Region (Ethiopia). *Journal of Camel Practice and Research*, **8**(1), pp. 51–54.

Singh, S., Mann, S., Kalsi, R., Singh, S., Taneja, N.K., Oberoi, H.S., Chauhan, K. and Taneja, P. (2024): Exploring the therapeutic and nutritional potential of camel milk: challenges and prospects: a comprehensive review. *Applied Food Research*, ***4***(2), p.100622.

Sisay, F. and Awoke, K. (2015): Review on production, quality and use of camel milk in Ethiopia. *Journal of Fisheries Livestock Production*, ***3***(145), p.2.

Swelum, A.A., El-Saadony, M.T., Abdo, M., Ombarak, R.A., Hussein, E.O., Suliman, G., Alhimaidi, A.R., Ammari, A.A., Ba-Awadh, H., Taha, A.E. and El-Tarabily, K.A. (2021): Nutritional, antimicrobial and medicinal properties of Camel's milk: A review. *Saudi journal of biological sciences*, ***28***(5), pp.3126-3136.

Tola, A. (2002): Traditional milk and milk products handling practices and raw milk quality in Eastern Wollega. *Alemaya University, Alemaya, Ethiopia*, *108*.

Tusa, H., Alemayehu, T., Subussa, B.W., Ayalew, H. and Ali, M.M. (2024): Hygienic practices of vendors and their contribution to coliform, Salmonella, and Shigella bacteria of raw milk at Asella Town, Oromia, Ethiopia. *International Journal of Food Science*, *2024*(1), p.8869022.

Vahedi, M., Nasrolahei, M., Sharif, M. and Mirabi, A. (2013): Bacteriological study of raw and unexpired pasteurized cow's milk collected at the dairy farms and super

markets in Sari city in 2011. *Journal of Preventive Medicine and Hygiene*, ***54***(2), p.120.

Wanjala, N.W., Matofari, J.W. and Nduko, J.M. (2016): Antimicrobial effect of smoking milk handling containers' inner surfaces as a preservation method in pastoral systems in Kenya. *Pastoralism*, ***6***(1), p.17.

Yohannes M, Z. and Gebru, G. (2007): Potentials of camel production in Babilie and Kebribeyah woredas of the Jijiga Zone, Somali Region, Ethiopia. *Livestock Research for rural development*, ***19***, pp.58-62.

Yosef, D.K., Ismail, A.S., Hassan, M.A. and Hassan, H.A. (2025): Demographic characteristics and camel milk production and handling practices in Burao City, Somaliland: implications for food safety. *Discover Food*, ***5***(1), p.324.

Younan, M., Kenyanjui, M., Wangoh, J., Nganga, A., Farah, Z. and Wasem, A. (2004): *Camel milk hygiene and mastitis: examples from Kenya and Somalia. Atelier Int. sur le lait de chamelle en Afrique*. FAO-CIRAD-KARKARA, Niamey (Niger), 71–78.

Zhumabay, A., Serikbayeva, A., Kozykan, S., Sarimbekova, S., Kossaliyeva, G. and Alimov, A. (2024): The importance of camel milk and its dairy products–a review. *Potravinarstvo*, *18*.

8. ANNEXES

Informed consent form

Hello, how are you? I am Geletu Gudeta Dekebo. Currently, I am a postgraduate student a t Addis Ababa University College of Veterinary Medicine and Agriculture, Department Of Veterinary Epidemiology and Public. Now I am conducting research on "**Assessment of Camel Milk Handling Practices and Bacterial Loads along the Value Chain in Borana and East Shewa, Ethiopia"**. I would appreciate your participation in this study. The objective of the study is to assess milk handling practices, and microbial quality of camel milk along the milk value chain in Borana and East Shewa, Ethiopia. To effectively attain the objective of the research, I am requesting your help. For your participation in the study, no payment will be granted or no special privilege to you. All information you give will be kept confidential and won't be accessible to any third party; your name won't be registered on the question sheet so you will not be identified for any reason. You have the right not to participate from the beginning, or you may stop participating at any time after starting the participation. However, your honest answers to these questions will help me in better understanding of camel milk handling practices, microbial quality of camel milk along the milk value chain and will eventually help in designing and implementing appropriate interventions to alleviate related problems.

Respondent statement: I have understood the above statements:

- Yes (Agree to participate)
- No (Not agree to participate)

Annex 1: Questionnaire for Camel milk producers

Section 1: Respondent information

1. Zone: ☐ Borana ☐ East Shewa
2. District: ☐ Yabelo ☐ Elwaya ☐ Gomole ☐ Fantale
3. What is your name? _____
4. ID in baseline survey: _____

Section 2: Milking and Milk Handling Practices

5. Do you wash your hands before milking camels?
   ☐ Always ☐ Sometimes ☐ Never
6. Do you wash your hands after milking camels?
   ☐ Always ☐ Sometimes ☐ Never

7. How do you clean your hands before milking?

☐ Use only water ☐ Use soap and water ☐ Use disinfectants or sanitizers

☐ Removing soil/ dust with cloth ☐ Others (specify)_____

8. What type of vessels do you use for milking? (multiple answers possible)

☐ Traditional wooden vessel ☐ Plastic bucket ☐ other (specify): _____

9. How often do you wash the milking vessels?

☐ After every milking ☐ Every day ☐ every two days, ☐ 3-4 times a week ☐ once a week

10. How do you clean /wash your milking vessels?

☐ Use only water ☐ Use water and soap ☐ Use disinfectants ☐ Other (specify): _____

11. What is the source of water for washing hands and milking vessels? (Multiple answers possible)

☐ Pipe/borehole ☐ spring ☐ Pond ☐ River ☐ deep well

12. How often do you smoke the milking vessels?

☐ Every day ☐ every two days, ☐ 3-4 times a week ☐ once a week ☐ never

Milk storage

13. What type of vessels do you use to **store** Camel **milk at home**? (Multiple answers possible)

☐ Wooden with wide mouth ☐ Plastic with wide mouth, ☐ Aluminum/Tin wide mouth

☐ Plastic with narrow mouth ☐other specify_____

14. How often do you clean the Camel **milk storage vessels**?

☐ Every day ☐ every two days, ☐ 3-4 times a week ☐ once a week ☐ never

15. Do you clean the storage vessels with soap or disinfectant? (Multiple answers possible)

☐ Soap ☐ Liquid detergent ☐ Disinfectant ☐ Other (specify): _____

16. How often do you smoke the storage vessels?

☐ Twice a day ☐ Every day ☐ every two days, ☐ 3-4 times a week ☐ once a week ☐ never

17. How is the Camel **milk stored** at home after milking?

☐ At room temperature ☐ In a refrigerator ☐ In a cool place

☐ Other (please specify) _____

18. How long do you store (keep) camel milk before it is further transported to the market (sold)?

☐ Less than 12 hours ☐ 12-24 hours ☐ More than 24 hours ☐ other (specify) _____

19. How do you enhance shelf life of milk (reduce spoilage) when milk is kept for more than one day? (Multiple answers possible)

☐ Boiling ☐ Smoking ☐ Use of herbs /plants ☐ Do-nothing

☐ Other (specify) _____

Milk transport

20. What type of vessel do you use to **transport** camel milk, e.g. to the market? (Multiple answers possible)

☐ Wooden with wide mouth ☐ Plastic with wide mouth, ☐ Aluminium/Tin wide mouth

☐ Plastic with narrow mouth ☐ Other (specify)_____

21. How often do you clean the Camel milk transport vessels? (Multiple answers possible)

☐ Every day ☐ Every second day ☐ 3-4 times a week ☐ Once a week ☐ Never

22. Do you clean the transport vessels with soap or disinfectant? (Multiple answers possible)

☐ Soap ☐ Liquid detergent ☐ Disinfectant ☐ Other (specify): _____

23. How often do you smoke the transport vessels?

☐ Every day ☐ Every second day ☐ 3-4 times a week ☐ Once a week ☐ Never

24. How long it takes to transport camel milk to market destination?

☐ Less than 2 hours ☐ 2-4 hours ☐ More than 4 hours

Milk consumption (by producers)

25. Which form of camel milk do you and your family often consume (Multiple choice possible)?

☐ Fresh raw milk ☐ Fermented milk ☐ Boiled milk, ☐ Milk boiled with tea

26. How often do you boil milk for children under 5 years old?

☐ Always ☐ Sometimes ☐ Never

27. How often do you boil Camel milk for yourself before consumption?

☐ Always ☐ Sometimes ☐ Never

28. How often do you boil Camel milk for pregnant women?

☐ Always ☐ Sometimes ☐ Never

29. How long camel milk is stored at your home before being consumed?

☐ Less than 1 day ☐ 1-3 days ☐ 3-5 days ☐ More than 5 days ☐ Other (specify): _____

Section 3: Awareness and Practices related to Food Safety, Hygiene and Sanitation

A) Knowledge questions

I will read statements for you, then answer the questions with either 'Yes' or 'No' or "Not sure".

Statements	**Yes**	**No**
1. Unclean milking area can contaminate camel milk and make people sick		
2. Milk from a camel with health problem can cause illness in human		
3. Raw camel milk is more likely to cause illness than boiled milk		
4. Consuming camel milk contaminated with camel faeces make people sick		
5. Consuming camel milk mixed with camel urine can cause illness in people		
6. Drug residue in camel milk can cause health risks in human		
7. Children, pregnant women or elders have higher risks of foodborne disease than health adults		
8. Having dirty hands when milking camels can affect quality and safety of milk		
9. Touching or grooming camel or calf while milking can contaminate milk		
10. Touching soil or camel faeces while milking camel can contaminate milk		
11. Drinking milk from aborting camels may cause illness in people		
12. Drinking spoiled camel milk may cause illness in people		

B) Practices

I will read statements for you, then answer the questions with either 'Yes' or 'No' or "Not sure".

Statements	Yes	No
1. Do you discard the first squirts of milk when milking camels?		
2. Do you boil camel milk before consumption?		
3. Do you touch (groom) calf or lactating camel during milking?		
4. Do you prevent yourself or a family member from handling camel milk when the individual has diarrhea?		
5. Do you prevent yourself or a family member from handling camel milk when the individual has a longstanding cough?		
6. Do you prevent yourself or a family member from milking camels when the individual has a wound on hands?		
7. Do you often avoid touching soil or camel faeces while milking camel		
8. Do you avoid consuming milk of camels receiving antibiotic (black or white medicine) injection?		
9. Do you avoid selling milk from camels treated with antibiotic injection		
10. Do you avoid drink or selling milk from sick camels		
11. Do you add urine or feces to milk for remedial or for any reason?		

Annex 2: Questionnaire for Collectors

Section 1: General demographic data of respondents

1. Zone: ☐ Borana ☐ East Shewa
2. District: ☐ Yabelo ☐ Elwaye ☐ Gomole ☐ Fantale
3. What is your name? _____ Telephone no: _____
4. Sex: ☐ Male ☐ Female
5. Age in years _____
6. Educational status of respondent: ☐Illiterate ☐Elementary school ☐ High school and Above
7. Marital status of the respondent: ☐ Single ☐ Married ☐ Divorced or Widowed ☐ Polygamy
8. What is your family's none-livestock source of income:

☐Crop production ☐Trading or mini-shops, ☐Selling milk ☐Selling products like charcoal, gum, incense ☐Handcraft ☐Renting a house ☐Casual labor ☐Others (specify)_____

9. What is your role in camel milk value chain?
   - ☐ Camel milk collector, ☐ Camel milk retailer / shop
   - ☐ Member of milk cooperative, ☐ Camel milk consumer
   - ☐ Owner of hotel / cafeteria selling camel milk
10. What is your major income source?
    - ☐ Livestock keeping, ☐ Crop farming
    - ☐ Other trading, ☐ wage and daily labourer based
    - ☐ Camel milk trading ☐ other, specify: _____

Section 2: Milk handling during transportation and storage

11. How do you transport Camel milk from a collection point (herd gate) to market, or shop, home?
    ☐ In a cool box ☐ using refrigerated truck ☐ At room temperature
12. What type of vessel do you use to transport Camel milk to market destination? (Multiple answers) e)

☐ Plastic with narrow mouth (jar-cane) ☐ Traditional vessel, ☐ Aluminum wide mouth ☐ Plastic with wide mouth ☐ other specify_____

13. How is camel milk stored after collection or before being sold?

☐ In a cool place ☐ In a refrigerator ☐ At room temperature
☐ Other (please specify) _____

14. How long do you keep camel milk before it is sold at market (retailer) or in the shop (hotel / cafeteria) or consumed (final consumer)?

☐ less than 12 hrs ☐ 12-24 hrs ☐ over 24 hrs, ☐ Other (specify) _____

15. How often do you clean the Camel milk transport vessels? (Multiple answers possible)

☐ Every day ☐ every two days, ☐ 3-4 times a week ☐ once a week ☐ never

16. Do you clean the transport vessels with soap or disinfectant? (Multiple answers possible)

☐ Soap ☐ Liquid detergent ☐ Disinfectant ☐ Other (specify): _____

17. What is the source of water for washing hands and milking vessels? (Multiple answers possible)

☐ Pipe/borehole ☐ spring ☐ Pond ☐ River ☐ deep well

18. How often do you smoke the transport vessels?

☐ Every day ☐ every two days, ☐ 3-4 times a week ☐ once a week ☐ never

19. In your opinion, what challenges do you face to ensure the hygienic quality of Camel milk during collection, transport and storage?

_____

20. Do you suspect non-milk substances are added to locally marketed milk? ☐ Yes ☐ No

Section 3: Camel milk consumption by collectors

21. Do you consume camel milk? ☐ Yes ☐ No

22. How frequent you consume fresh raw camel milk?
☐ Never (don't consume) ☐ At least once weekly ☐ Sometimes (as available) ☐ Everyday

23. How frequent do you consume boiled camel milk?
☐ Never (don't consume) ☐ At least once weekly ☐ Sometimes (as available) ☐ Everyday

24. How often do you boil milk for the following groups? (3=always 2=sometimes, 1=rarely 0= never)

Population at risk	children under 5 years old	Pregnant women	Elderly (old) / sick people	For your own consumption
Scale (0,1,2,3)				

25. Do you have any concern regarding the quality of camel milk coming from herders and sold here?
☐Yes ☐ No

26. How long camel milk is stored (kept) at your home before being consumed?
☐ Less than 1 day ☐ 1-3 days ☐ 3-5 days ☐ More than 5 days
☐ Other (specify): _____

27. Do you have any concern, regarding the camel milk quality and safety?
☐ Yes ☐ No

Annex 3: Questionnaire for Retailers

Section 1: General demographic data of respondents

28. Zone: ☐ Borana ☐ East Shewa
29. District: ☐ Yabelo ☐ Elwaye ☐ Gomole ☐ Fantale
30. What is your name? _____ Telephone no: _____
31. Sex: ☐ Male ☐ Female
32. Age in years _____
33. Educational status of respondent: ☐Illiterate ☐Elementary school ☐ High school and Above

34. Marital status of the respondent: ☐ Single ☐ Married ☐ Divorced or Widowed ☐ Polygamy
35. What is your family's none-livestock source of income:

☐Crop production ☐Trading or mini-shops, ☐Selling milk ☐Selling products like charcoal, gum, incense ☐Handcraft ☐Renting a house ☐Casual labor ☐Others (specify)_____

36. What is your role in camel milk value chain?

☐ Camel milk collector, ☐ Camel milk retailer / shop
☐ Member of milk cooperative, ☐ Camel milk consumer
☐ Owner of hotel / cafeteria selling camel milk

37. What is your major income source?

☐ Livestock keeping, ☐ Crop farming
☐ Other trading, ☐ wage and daily labourer based
☐ Camel milk trading ☐ other, specify: _____

Section 2: Milk handling during transportation and storage (by non-producer respondent)

38. How do you transport Camel milk from a collection point (herd gate) to market, or shop, home?

☐ In a cool box ☐ using refrigerated truck ☐ At room temperature

39. What type of vessel do you use to transport Camel milk to market destination? (Multiple answers) e)

☐ Plastic with narrow mouth (jar-cane) ☐ Traditional vessel, ☐ Aluminum wide mouth ☐ Plastic with wide mouth ☐ other specify_____

40. How is camel milk stored after collection or before being sold?

☐ In a cool place ☐ In a refrigerator ☐ At room temperature
☐ Other (please specify) _____

41. How long do you keep camel milk before it is sold at market (retailer) or in the shop (hotel / cafeteria) or consumed (final consumer)?

☐ Less than 12 hrs ☐ 12-24 hrs ☐ over 24 hrs, ☐ Other (specify) _____

42. How often do you clean the Camel milk transport vessels? (Multiple answers possible)

☐ Every day ☐ every two days, ☐ 3-4 times a week ☐ once a week ☐ never

43. Do you clean the transport vessels with soap or disinfectant? (Multiple answers possible)

☐ Soap ☐ Liquid detergent ☐ Disinfectant ☐ Other (specify): _____

44. What is the source of water for washing hands and milking vessels? (Multiple answers possible)

☐ Pipe/borehole ☐ spring ☐ Pond ☐ River ☐ deep well

45. How often do you smoke the transport vessels?

☐ Every day ☐ every two days, ☐ 3-4 times a week ☐ once a week ☐ never

46. Do you suspect non-milk substances are added to locally marketed milk? ☐ Yes ☐ No

Section 3: Camel milk consumption by retailers

Do you consume camel milk? ☐ Yes ☐ No

47. How frequent you consume fresh raw camel milk?

☐ Never (don't consume) ☐ At least once weekly ☐ Sometimes (as available) ☐ Everyday

48. How frequent do you consume boiled camel milk?

☐ Never (don't consume) ☐ At least once weekly ☐ Sometimes (as available) ☐ Everyday

49. How often do you boil milk for the following groups? (3=always 2=sometimes, 1=rarely 0= never)

Population at risk	children under 5 years old	Pregnant women	Elderly (old) / sick people	For your own consumption
Scale (0,1,2,3)				

50. Do you have any concern regarding the quality of camel milk coming from herders and sold here?

☐Yes ☐ No

51. How long camel milk is stored (kept) at your home before being consumed?

☐ Less than 1 day ☐ 1-3 days ☐ 3-5 days ☐ More than 5 days

☐ Other (specify): _____

Do you have any concern, regarding the camel milk quality and safety?

☐ Yes ☐ No

Annex 4: Questionnaire for Cafeteria owners

Section 1: General demographic data of respondents

52. Zone: ☐ Borana ☐ East Shewa

53. District: ☐ Yabelo ☐ Elwaye ☐ Gomole ☐ Fantale

54. What is your name? _____ Telephone no: _____

55. Sex: ☐ Male ☐ Female

56. Age in years _____

Section 2: Milk handling during transportation and storage (by non-producer respondent)

57. How frequent do your customers consume camel milk?

☐ Never ☐ Sometimes ☐ Everyday

58. If your customer consume, how often do you supply raw camel milk?

☐ Never ☐ Sometimes ☐ Everyday

59. If your customer consume, which type of camel milk do you supply?

☐ Fresh raw ☐ Fermented milk ☐ Boiled milk ☐ Boiled with tea

60. What are the common sources of camel milk contamination?

☐ Dirty udder ☐ unclean containers ☐ unclean hands ☐ infected camels

61. How long can fresh camel milk stored safe for consumption without refrigeration in your organization?

☐ <2 hrs ☐ 2-6 hrs ☐ 6-12 hrs ☐ >12 hrs

Annex 5: Questionnaire for Camel milk cooperatives

Section 1: General demographic data of respondents

62. Zone: ☐ Borana ☐ East Shewa

63. District: ☐ Yabelo ☐ Elwaye ☐ Gomole ☐ Fantale

64. What is your name? _____ Telephone no: _____

65. Sex: ☐ Male ☐ Female

66. Age in years _____

67. Educational status of respondent: ☐Illiterate ☐Elementary school ☐ High school and Above

68. Marital status of the respondent: ☐ Single ☐ Married

69. What is your family's none-livestock source of income:

☐Crop production ☐Trading or mini-shops, ☐Selling milk ☐Selling products like charcoal, gum, incense ☐Handcraft ☐Renting a house ☐Casual labor ☐Others (specify)_____

Section 2: Milk handling and storage

70. How do you store camel milk from a collection point in your shop?

☐ In a cool box ☐ using refrigerated truck ☐ at room temperature

71. What type of vessel do you use to store camel milk at your shop until selling??

☐ Plastic with narrow mouth (jar-cane) ☐ Traditional vessel, ☐ Aluminum wide mouth ☐ Plastic with wide mouth ☐ other specify_____

72. How do you store camel milk from a collection point in your shop?

☐ In a cool box ☐ using refrigerated truck ☐ at room temperature

73. Do you smoke camel milk storage vessels?

☐ Yes ☐ No

74. If you may use smoke to clean vessel, how often do you smoke the storage vessels?

75. How often do you smoke the storage vessels?

☐ Every day ☐ twice a day ☐ 3-4 times a week ☐ once a week

How long do you store (keep) camel milk before it is further transported to the market (sold)?

76. How long do you store camel milk before it is further transported to the market?

☐ Less than 12 hrs ☐ 12-24 hrs ☐ over 24 hrs, ☐ other (specify) _____

Annex 6: Questionnaire for Consumers

Section 1: General demographic data of respondents

77. Zone: ☐ Borana ☐ East Shewa

78. District: ☐ Yabelo ☐ Elwaye ☐ Gomole ☐ Fantale

79. What is your name? _____ Telephone no: _____

80. Sex: ☐ Male ☐ Female

81. Age in years _____

82. Educational status of respondent: ☐Illiterate ☐Elementary school ☐ High school and Above

83. Marital status of the respondent: ☐ Single ☐ Married ☐ Divorced or Widowed

Section 2: Camel milk consumption and handling

84. How often do you consume fresh raw camel milk?

☐ Never (don't consume) ☐ At least once weekly ☐ Sometimes (as available) ☐ Everyday

85. How often do you boil milk for the following groups? (3=always 2=sometimes, 1=rarely 0= never)

Population at risk	children under 5 years old	Pregnant women	Elderly (old) sick people	For your own consumption
Scale (0,1,2,3)				

86. Do you have any concern, regarding the camel milk quality and safety? ☐ Yes ☐ No

87. If camel milk is not consumed within a day, how do keep at your home?

☐ In a cool box ☐ in refrigerated ☐ at room temperature

88. What are the common sources of camel milk contamination?

☐ Dirty udder ☐unclean containers ☐ unclean hands ☐ infected camels

Annex 7: Questionnaire for Experts from NGO and Government organization

Section 1: General data of Experts and their Institutions (experts from GO or NGO)

1. Zone: ☐ Borana ☐ East Shewa
2. District: ☐ Yabelo ☐ Elwaya ☐ Gomole ☐ Fantale
3. What is your name? _____ Telephone no: _____
4. Sex: ☐ Male ☐ Female
5. Age in years _____

Section II: Camel milk consumption and Hygienic status

6. How frequent do you consume camel milk?
   ☐ Never (don't consume) ☐ At least once monthly ☐ Sometimes (once a week) ☐ Everyday
7. If you consume, how often do you consume raw camel milk?
   ☐ Never (don't consume) ☐ At least once monthly ☐ Sometimes (once a week) ☐ Everyday
8. If you consume, which type of camel milk do you often consume?
   ☐ Fresh raw ☐ Fermented milk ☐ Boiled milk ☐ Boiled with tea
9. What are the common sources of contamination of camel milk (multiple answers)?
   ☐ Dirty udder ☐ Unclean containers ☐ Unclean hands ☐ Infected camels
10. Are you aware of zoonotic diseases transmitted through camel milk (e.g., brucellosis, Tb)?
    ☐ Yes ☐ No ☐ Not sure
11. How long can fresh camel milk remain (stay) safe for consumption without refrigeration?
    ☐ <2 hours ☐ 2–6 hours ☐ 6–12 hours ☐ >12 hours ☐ Not sure
12. How concerned are you about the safety of raw camel milk consumed without boiling?
    ☐ Very Concerned ☐ Somewhat Concerned ☐ Not Concerned ☐ Not sure
13. Are you aware that drug residue of antibiotics used to treat lactating camels can have health risk?
    ☐ Yes ☐ No ☐ Not sure

Annex 8: Procedures for preparation of different media

1. Buffered Peptone Water (BPW) (Accumix, India)

20 grams of dehydrated medium was added to 1 liter of distilled water. Mixed well and distributed into final containers. Then, it was sterilized by autoclaving at 121°C for 15 minutes. **Composition (gram/liter)**: Peptone 10.0, Sodium chloride 5.0, Disodium phosphate 3.5, Potassium dihydrogen phosphate 1.5, pH 7.2 ± 0.2 at 25°C.

2. Plate count agar (Accumix, India)

Composition (gram/liter): Enzymatic digest of casein 5.0 g, Yeast extract 2.5g, Dextrose 1.0 g, Agar: 9.0 g to 15.0 g, Final pH: 7.0 ± 0.2 at 25°C.

Preparation:

1. Suspend 23.5 grams in 1000 ml distilled water.
2. Heat to boiling to dissolve the medium completely.
3. Sterilize by autoclaving at 15 lbs pressure (121°C) for 15 minutes.
4. Cool to 45-50°C.

Procedures of bacterial load count

5. One milliliter (1 ml) of milk sample will be serially diluted in 9 ml of peptone water (ratio of 1:10) up to six dilutions.
6. Sterile duplicate glass petri dishes are labeled according to the dilution index.
7. One ml of the dilutions was aseptically with drawn using a sterile 1 ml Pasteur pipette and was delivered into an opened and sterile petri dish and then closed, the same procedure done for a duplicate petri dish.
8. This was repeated till all the dilutions are pipetted into their corresponding plates up to 10^{-6}. This was followed by pouring about 15 ml of standard plate count agar which had been autoclaved at 121 °C for 15 min, cooled and tempered in a water bath at 50 °C.
9. The sample and the agar are gently mixed by alternate clock and anti-clockwise rotations and left to solidify on the bench for about 30 min.
10. The plates are inverted and incubated at 37 °C for 48 h.
11. After incubation, plates inoculated with sample dilution yielding between 30 and 300 colonies are counted. Colony counts are made using colony counter.

3. Violet red bile agar (M049-500G)

Composition (gram/liter): Lactose 10.0 g, Sodium Chloride 5.0 g, Yeast Extract: 3.0 g, Bile Salts Mixture: 1.5 g, Neutral Red: 0.03 g, Crystal Violet: 0.002 g, Agar: 12.0 – 15.0 g, Final pH: 7.4 ± 0.2 at 25° C.

Preparation:

1. Suspend 41.53 grams in 1000 ml distilled water.
2. Heat with stirring to boiling to dissolve the medium completely.
   Note: Do not autoclave
3. Cool to 45°C and pour into sterile Petri plates containing the inoculum.

Procedures of Coliform count

4. One ml of milk sample was added into sterile test tube having 9 ml of peptone water.
5. After mixing, the sample was serially diluted up to 1: 10^{-6}.
6. 1 ml of inoculum will be mixed thoroughly with molten 15 ml Violet Red Bile Agar solution which was previously held in a water bath at 50 °C.
7. Two plates were inoculated with each dilution. After thoroughly mixing, the plated sample is allowed to solidify and then incubated at 37 °C for 24 hours.
8. Typical dark red colonies are considered as coliform colonies. Finally, colony counts were done using colony counter.



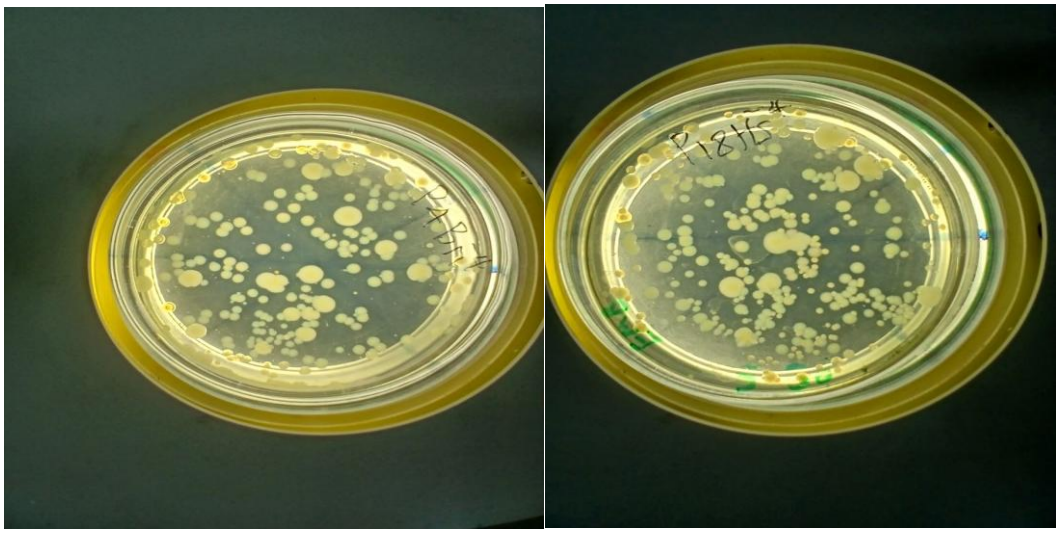
Annex 9: Media used for serial dilution, total bacterial count, coliform count



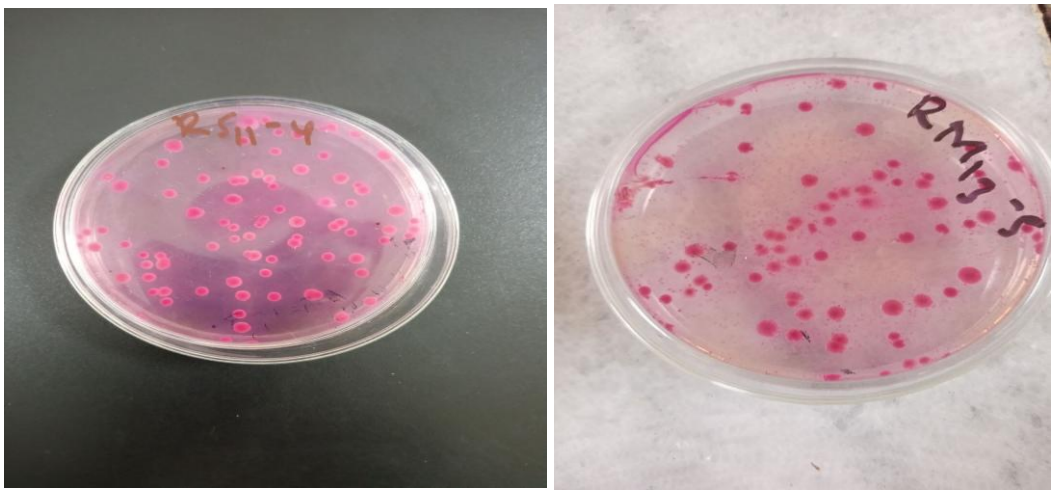
Annex 10: Photo taken during sample collection



Annex 11: Photo taken during laboratory activities



Annex 12: Photo of aerobic plate count colony



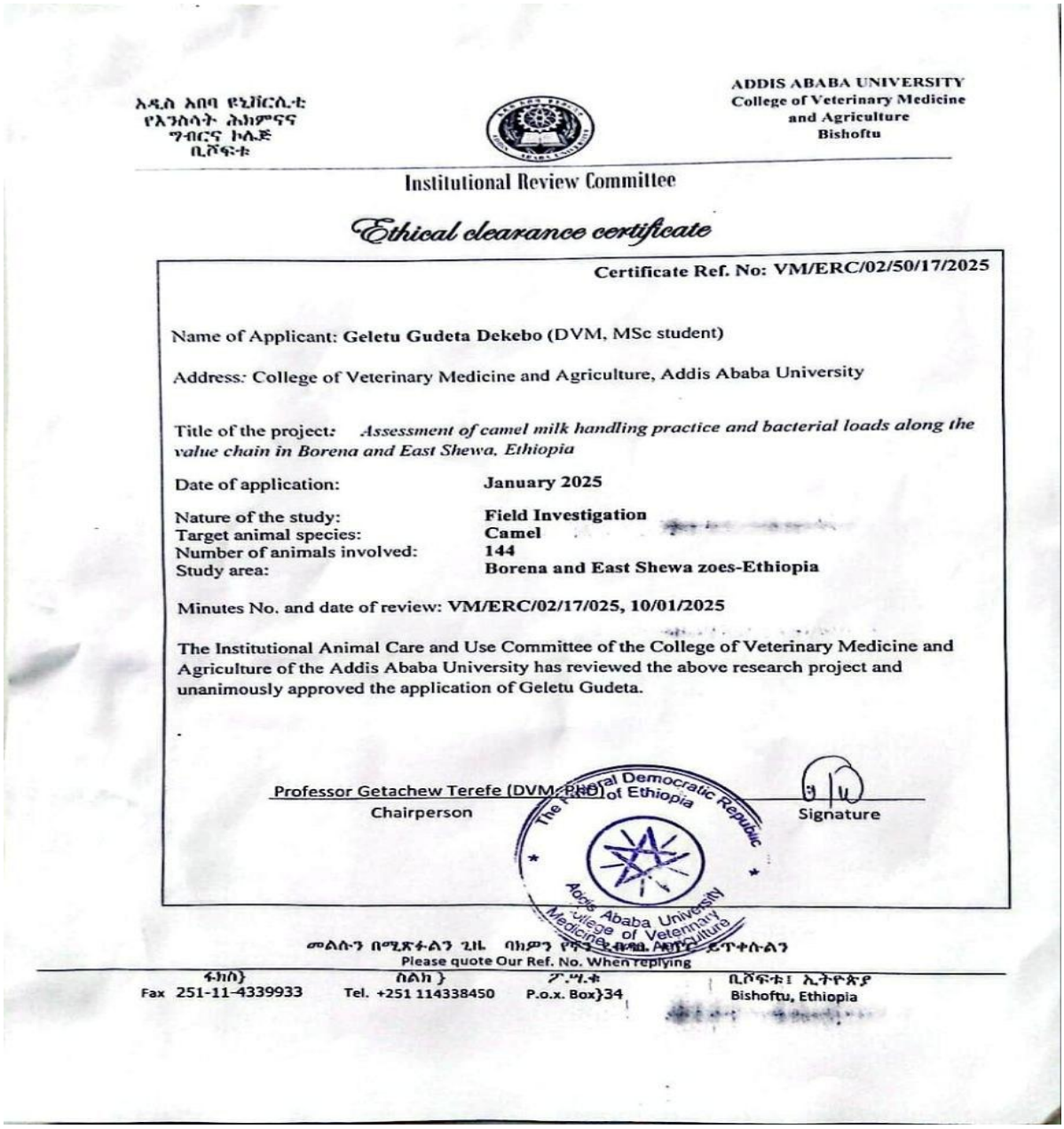
Annex 13: Photo of coliform count colony






Annex 14: Photo taken during questionnaires with value chain actors

Annex 15: Ethical clearance



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ADDIS ABABA UNIVERSITY
College of Veterinary Medicine
and Agriculture
Bishoftu

Institutional Review Committee

Ethical clearance certificate

Certificate Ref. No: VM/ERC/02/50/17/2025

Name of Applicant: **Geletu Gudeta Dekebo (DVM, MSc student)**

Address: College of Veterinary Medicine and Agriculture, Addis Ababa University

Title of the project: *Assessment of camel milk handling practice and bacterial loads along the value chain in Borena and East Shewa, Ethiopia*

Date of application: **January 2025**

Nature of the study: **Field Investigation**
Target animal species: **Camel**
Number of animals involved: **144**
Study area: **Borena and East Shewa zoes-Ethiopia**

Minutes No. and date of review: **VM/ERC/02/17/025, 10/01/2025**

The Institutional Animal Care and Use Committee of the College of Veterinary Medicine and Agriculture of the Addis Ababa University has reviewed the above research project and unanimously approved the application of Geletu Gudeta.

Professor Getachew Terefe (DVM, PhD)
Chairperson

Signature

The Federal Democratic Republic of Ethiopia
Addis Ababa University
College of Veterinary Medicine and Agriculture

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