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Bacteriological Load of Raw Camel Milk Along the Value Chain in Peri-Urban Dairy Farms around Burao, Somaliland

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Abstract

Camel milk is an important food in Somaliland, but the bacteriological quality of milk along the peri-urban value chain is poorly documented. This study quantified bacterial contamination at three chain points around Burao. In this cross-sectional study, eight of 30 peri-urban dairy camel farms were selected by stratified sampling, and three raw milk samples were collected per farm (n = 24): directly from the udder, from transport containers and from market containers. Total plate count (TPC) and coliform count were determined by the pour-plate method, aerobic spore-forming bacteria by plate counts after heat treatment at 80°C, and *Salmonella* spp. by pre-enrichment, selective enrichment, selective plating and biochemical confirmation. Counts are expressed as $\log_{10}$ colony-forming units per milliliter (log CFU/mL) (mean ± standard error). Mean TPC was 8.19 ± 0.07 log CFU/mL overall (udder 8.16 ± 0.06; transport 8.24 ± 0.12; market 8.17 ± 0.19), about 1.9 log units above the Kenya Bureau of Standards (KEBS) limit of 2×10^6 CFU/mL (6.30 log CFU/mL). Mean coliform counts were 6.17 ± 0.11, 6.24 ± 0.12 and 6.31 ± 0.14 log CFU/mL at the same points, above the KEBS limit of 1×10^6 CFU/mL (6.00 log CFU/mL). *Salmonella* spp. was detected in 4 of 24 samples (16.7%); 3 samples were spoiled. All 24 samples were classified as poor for spore-forming bacteria. Temperature (27.0–28.0°C) and pH (6.10–6.22) differed little among chain points. Raw camel milk was heavily contaminated already at the udder, and the milk was uncooled throughout, indicating that contamination originates at farm level and is not reduced downstream. Training of herders and vendors in milking hygiene, udder and utensil cleaning with safe water, prompt cooling, and boiling or pasteurization before consumption are recommended.

Highlights

- Mean TPC was 8.19 log CFU/mL, about 1.9 log above the KEBS limit
- Coliforms rose from 6.17 (udder) to 6.31 log CFU/mL (market)
- Salmonella spp. was detected in 4 of 24 raw camel milk samples (16.7%)
- All 24 samples were rated poor for spore-forming bacteria
- Counts were already high at the udder; milk stayed uncooled at 27–28 °C

1. Introduction

The dromedary camel (*Camelus dromedarius*) was domesticated about 3000–2500 BC and has since supplied transport, milk, meat and fiber to pastoral societies (Almathen et al., 2016). Its tolerance of heat and of feed and water scarcity makes it a mainstay of livelihoods in arid lands where other livestock and crops fail (Faye, 2015). Among Somali communities, camels carry high cultural and economic value, and camel milk is a staple that can supply a substantial share of nutrient needs during food scarcity (Farah, 1996). In Burao, Somaliland, 90.1% of surveyed camel milk producers considered camel milk an important part of the diet (Yosef et al., 2025).

Milk is rich in nutrients and is therefore an excellent growth medium for microorganisms. Raw milk can carry pathogens such as *Salmonella* spp. and *Escherichia coli* O157:H7, and consumption of unpasteurized milk remains a recognized public-health threat (Angulo et al., 2009; Oliver et al., 2009). Foodborne diseases caused an estimated 33 million disability-adjusted life years globally in 2010, with the heaviest burden in Africa and 40% borne by children under five years (Havelaar et al., 2015). Poor milk hygiene also shortens shelf life and contributes to post-harvest milk losses along camel milk value chains (Odongo et al., 2016).

Milk from a healthy udder is initially of low microbial content; most contamination occurs after secretion, from teat skin, milkers' hands, utensils, water and the environment, and is amplified during storage and transport (Quigley et al., 2013; Shukla et al., 2019). Along the Kenyan camel milk chain, mean total viable counts rose from 4.91 log CFU/mL (colony-forming units per millilitre) at production to 7.52 log CFU/mL at the Nairobi market, and coliforms from 3.68 to 6.42 log CFU/mL (Nato et al., 2018). Time to market, container type and handling hygiene were identified as predisposing factors (Mwangi et al., 2016; Nato et al., 2018). Increases in counts between production and market, linked to long uncooled transport, have also been reported in Ethiopia (Abera et al., 2016; Adugna et al., 2013), and heat-resistant aerobic spore-forming bacteria have been isolated from commercial camel milk (Ziane et al., 2016).

The Code of Hygienic Practice for Milk and Milk Products (Codex Alimentarius Commission, 2004) sets out good practice from primary production onwards, including animal health, milking hygiene, water quality and time–temperature control. Numerical criteria specific to camel milk are scarce. The Kenya Bureau of Standards (KEBS, 2017) sets limits of 2×10^6 CFU/mL for total plate count and 1×10^6 CFU/mL for coliforms, whereas other authors note that no widely adopted camel milk standard exists in Africa and that cow milk limits are often applied (Gitau et al., 2022). In Burao, a survey of 384 camel milk producers found that only 13.0% consistently washed their hands before milking, 84.1% never cleaned the udder, 96.5% used plastic containers and 12.5% had received hygiene training; the milk itself was not tested microbiologically (Yosef et al., 2025).

2. Materials and Methods

2.1 Study area

The study was conducted along the camel milk value chain of peri-urban dairy camel farms around Burao, the capital of the Togdheer region of Somaliland (9°52'59" N, 45°53'46" E). The region has a dense camel population, and semi-intensive dairy camel farms operate around the town. Milk from these farms is transported daily to Burao in stainless-steel containers carried by pickup trucks and is sold at market centers.

2.2 Study design and sample collection

A cross-sectional design was used. Eight farms were selected by stratified sampling from a list of 30 peri-urban camel dairy farms. On each farm, three raw milk samples were collected at different points of the chain: (i) directly from the udder of an individual lactating camel, (ii) from the transport container and (iii) from the market-centre container, giving 24 samples (eight per chain point). The camels sampled were privately owned lactating dromedary camels (*Camelus dromedarius*) belonging to the owners of the selected farms; no animals were purchased or obtained from a commercial source, and verbal informed consent was obtained from each farm owner before sampling. Udder samples were collected by a member of the research team, who hand-milked an individual lactating camel directly into a sterile bottle during the routine morning milking; no procedure other than milking was performed on the animals. Samples were collected in the morning into sterile screw-capped bottles, transported in an icebox to the laboratory of the Faculty of Veterinary Medicine and Animal Production, University of Burao, and analyzed on the day of collection.

2.3 Physicochemical analysis

Milk temperature and pH were measured with a portable Hanna HI 9813-6 meter (Hanna Instruments).

2.4 Microbiological analysis

Total plate count (TPC). TPC was determined by the pour-plate method on plate count agar (HiMedia), autoclaved at 121°C for 15 min and tempered at 50°C in a water bath. One milliliter of milk was serially diluted (1:10) in peptone water up to 10^{-6} with an automatic pipette and sterile tips. Dilutions were transferred to duplicate sterile plastic Petri dishes, overlaid with 12–15 mL of tempered agar, allowed to set, and incubated inverted at 37°C for 48 h.

Coliform count. One milliliter of milk was diluted in 9 mL of peptone water and serially diluted up to 10^{-5}. Dilutions were transferred to duplicate sterile disposable Petri dishes, overlaid with 20 mL of violet red bile agar and incubated at 37°C for 24 h. Colonies were counted manually with a hand lens.

Aerobic spore-forming bacteria. Samples were heated to 80°C in a water bath and cooled to room temperature. Samples were serially diluted, plated on plate count agar in sterile disposable Petri dishes and incubated at 37°C for 48 h. Only mesophilic spore-formers were enumerated; thermophilic spore-formers were not assessed because of instrument limitations. Samples were classified as good, fair or poor.

Salmonella spp. A 25-mL portion of milk was added to 225 mL of peptone water and incubated at 36°C for 20 h. Then 0.1 mL of the pre-enrichment culture was transferred to 10 mL of Rappaport–Vassiliadis soya (RVS) broth and incubated at 42°C for 24 h. Cultures were streaked with a loop onto *Salmonella–Shigella* agar and incubated at 37°C for 24 h. Suspect colonies were inoculated into triple sugar iron agar in screw-capped tubes and incubated at 37°C for 24 h for confirmation. Samples that deteriorated during testing were recorded as spoiled.

2.5 Data analysis

Bacterial counts were $\log_{10}$-transformed and are presented as log CFU/mL, as mean ± standard error (SE) for each chain point (n = 8) and overall (n = 24). *Salmonella* and spore-former results are presented as frequencies and percentages. Counts were compared with the KEBS (2017) limits of 2 × 10⁶ CFU/mL (6.30 log CFU/mL) for TPC and 1 × 10⁶ CFU/mL (6.00 log CFU/mL) for coliforms, and with the hygiene guidance of the Codex Alimentarius Commission (2004).

3. Results

3.1 Physicochemical properties

Overall mean milk temperature was 27.4 ± 0.26°C. Temperature and pH varied little among the three chain points (Table 1): temperature ranged from 27.03 to 28.02°C and pH from 6.10 to 6.22, with milk from market containers being the warmest.

3.2 Total plate count and coliform count

Overall mean TPC was 8.19 ± 0.07 log CFU/mL (Table 1). Mean TPC was 8.16 ± 0.06 log CFU/mL in udder milk, 8.24 ± 0.12 in transport containers and 8.17 ± 0.19 in market containers; the difference between the lowest and highest means was 0.08 log CFU/mL. At every chain point the mean exceeded the KEBS limit of 6.30 log CFU/mL (2 × 10⁶ CFU/mL) by 1.86–1.94 log units.

Mean coliform counts were 6.17 ± 0.11, 6.24 ± 0.12 and 6.31 ± 0.14 log CFU/mL in udder, transport and market milk, respectively, a numerical increase of 0.14 log CFU/mL from udder to market. All three means were above the KEBS limit of 6.00 log CFU/mL (1 × 10⁶ CFU/mL), by 0.17–0.31 log units.

Table 1
Temperature, pH, total plate count (TPC) and coliform count of raw camel milk at three points of the peri-urban value chain around Burao (mean ± standard error, n = 8 per point)

Chain point	Temperature (°C)	pH	TPC (log CFU/mL)	Coliforms (log CFU/mL)
Udder	27.33 ± 0.31	6.22 ± 0.02	8.16 ± 0.06	6.17 ± 0.11
Transport containers	27.03 ± 0.41	6.10 ± 0.06	8.24 ± 0.12	6.24 ± 0.12
Market containers	28.02 ± 0.65	6.15 ± 0.06	8.17 ± 0.19	6.31 ± 0.14

3.3 *Salmonella* and spore-forming bacteria

Salmonella spp. were detected in 4 of 24 samples (16.7%); 17 samples (70.8%) were negative and 3 (12.5%) were spoiled during testing (Table 2). Among the 21 interpretable samples, 4 (19.0%) were positive. All 24 samples (100%), eight at each chain point, were classified as poor for aerobic spore-forming bacteria; none was classified as fair or good (Table 3).

Table 2
Salmonella spp. in raw camel milk samples (n = 24)

Result	Samples (n)	Percentage (%)
Negative	17	70.8
Positive	4	16.7
Spoiled	3	12.5

Table 3
Classification of aerobic spore-forming bacteria by chain point (number of samples)

Class	Udder	Transport containers	Market containers	Total (%)
Poor	8	8	8	24 (100)
Fair	0	0	0	0 (0)
Good	0	0	0	0 (0)

4. Discussion

Bacterial loads were high at every point of the chain. Mean TPC was roughly 80-fold above the KEBS limit, and mean coliform counts were also above the limit, so by these criteria the milk would be considered contaminated. The counts exceed those reported along the Kenyan market chain, where TVC reached 7.52 log CFU/mL and coliforms 6.42 log CFU/mL at the Nairobi market (Nato et al., 2018), and are far above the median count of 3.6×10^3 CFU/mL reported for camel milk in Isiolo County, Kenya (Gitau et al., 2022). High loads have likewise been described in camel milk from Ethiopia and Egypt (Abera et al., 2016; Adugna et al., 2013; Elhosseny et al., 2018; Mohammed et al., 2016). Differences in methods and in the limits applied restrict direct comparison.

Counts did not increase appreciably along the chain: TPC differed by less than 0.1 log CFU/mL among points and coliforms rose only modestly. This contrasts with Kenya, where TVC rose by 2.6 log units between production and market (Nato et al., 2018). Because udder-point milk already carried the load found downstream, contamination most likely occurred at or before milking, and the short distance between farm and market probably limited further growth. This interpretation is consistent with the hygiene practices reported by Burao producers, namely infrequent hand washing, uncleaned udders and plastic containers (Yosef et al., 2025), and with the emphasis that the Codex code places on clean udders, equipment and water at primary production (Codex Alimentarius Commission, 2004). Udder-point samples were drawn at milking and therefore reflect hands, teat skin, containers and surroundings as well as the udder itself; udder health was not assessed, so intramammary infection cannot be excluded (Angulo et al., 2009).

Milk was at 27–28°C at every point, that is, uncooled, whereas the Codex code calls for time–temperature control to limit microbial growth (Codex Alimentarius Commission, 2004). Short transport times may explain why counts did not increase further, but this margin would disappear with longer distances or delays. The pH values (6.10–6.22) fall within ranges reported for fresh camel milk (Adugna et al., 2013; Ismaili et al., 2019; Yamina et al., 2013) and differ from fermented camel milk (Yam et al., 2014). That pH remained in the fresh-milk range despite counts above 8 log CFU/mL suggests that pH alone does not reveal bacterial contamination at this stage.

Salmonella spp. were detected in 16.7% of samples (19.0% of the 21 interpretable samples). Salmonellae are shed in faeces and persist in water, soil and food, so faecal contamination of udders, hands or cleaning water is a plausible route. Reported prevalence in camel milk varies widely among surveys (El-Ziney & Al-Turki, 2007; Matofari et al., 2007), and with only 24 samples the estimate is imprecise (exact 95% confidence interval 4.7–37.4%). Non-typhoidal *Salmonella enterica* is a leading cause of diarrhoeal deaths worldwide (Havelaar et al., 2015), so any detection in milk is of concern, particularly for young children and other vulnerable consumers.

The classification of all samples as poor for aerobic spore-forming bacteria points to soil, dust and faecal contamination of udders and utensils, which is plausible given the dusty enclosures and water of uncertain quality described by the authors' field observations. This finding is higher than the low spore counts reported in other studies (El-Ziney & Al-Turki, 2007; Mwangi et al., 2016). Spore-formers are heat resistant and have been isolated from commercial camel milk (Ziane et al., 2016), so pasteurisation alone will not remove them if initial loads are high (Quigley et al., 2013).

Two practical implications follow. First, boiling or pasteurising milk before consumption would reduce the risk from vegetative pathogens such as *Salmonella*, although verifying heat treatment in camel milk is not straightforward because alkaline phosphatase, the usual marker in cow milk, retains residual activity (Seifu, 2023). Second, because contamination arose at farm level, interventions should start with milking hygiene, safe water, cleaning of utensils and cooling. Training is needed, since only 12.5% of Burao producers reported hygiene training (Yosef et al., 2025), but training alone was not associated with significantly lower counts in Kenya (Nato et al., 2018) and should be paired with access to water and equipment.

This study has limitations. It covered eight farms on a single occasion (n = 24), the stratification criteria and the farm-level practices at sampling were not recorded, spore-formers were classified rather than counted and only mesophilic spore-formers were assessed, *Salmonella* was detected by culture without serotyping, and three samples were lost to spoilage. Comparisons with standards used mean rather than individual-sample counts. The findings apply to peri-urban farms around Burao and should be confirmed in larger, repeated surveys.

5. Conclusions and Recommendations

Raw camel milk from peri-urban farms around Burao exceeded the KEBS limits for total plate count and coliforms at all three chain points, *Salmonella* spp. was detected in 4 of 24 samples, and all samples were poor for spore-forming bacteria. Because counts were already high at the udder and the milk was uncooled throughout, contamination appears to originate at farm level rather than during transport or marketing.

We recommend

1. training of herders and milk vendors in hygienic milking and handling,
2. washing of udders and hands and cleaning of utensils with safe water,
3. prompt cooling and shorter holding times, and
4. boiling or pasteurization of milk before consumption. Larger, repeated surveys that identify contamination sources and test the effect of these interventions are needed.

Declarations

Ethics approval and consent to participate

The study was approved by the Research Ethics Committee of the Faculty of Veterinary Medicine, University of Burao, Somaliland (approval reference number **UoB/FVM/64/2026**, dated **April/21/2026**). The study involved only the collection of raw milk samples from privately owned lactating dromedary camels on eight peri-urban dairy farms around Burao; no experimental procedure or treatment was applied to the animals. Udder samples were obtained by a member of the research team by hand-milking, in the same manner as routine milking, and the camels were not subjected to any handling beyond normal milking. Permission to collect milk samples from the farms was also granted by the Ministry of Livestock and Rural Development, Togdheer Regional Office, Burao, Somaliland. All procedures were carried out in accordance with national legislation, with the ARRIVE guidelines and with the principles of the Basel Declaration. Verbal informed consent was obtained from the owners of all eight farms before sampling, after the purpose and procedures of the study had been explained to them.

Consent to publish

Not applicable.

Author Contribution

A.S. Ismail work in conceptualization, field data collection, data entry and analysis. S.S. Ismail work on conceptualization, data analysis; writing; review. A.M. Jama work on data field data collection and data entry. A.S. Ismail Work in data entry and analysis. S.S. Ismail work in conceptualization and review. All authors involved in validation and editing.

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Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Figures

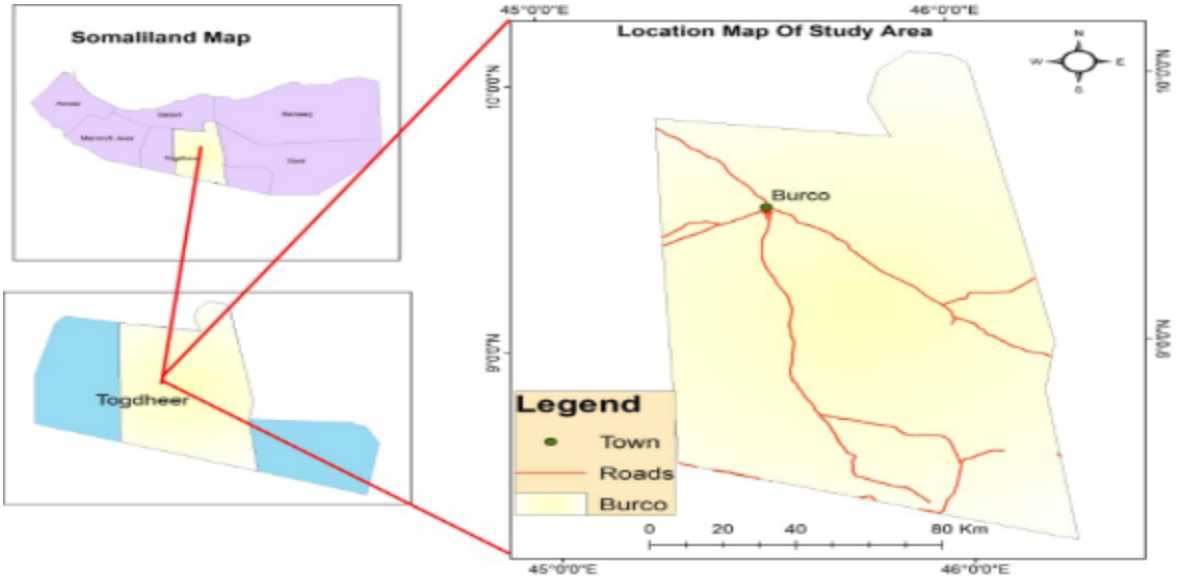


Figure 1

Unnumbered image in the 2. Materials & Methods section.

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