

Assessment of Milking Hygiene Practices and Raw Goat Milk Quality: A Case Study of a Dairy Goat Farm in Narathiwat Province, Thailand

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Abstract

The quality of raw goat milk is largely affected by farm management and milking hygiene, especially in small-scale production systems. This study aimed to assess milking hygiene practices and their relationship with the physical, chemical, and microbiological quality of raw goat milk from a dairy goat farm in Southern Thailand. Milking practices were evaluated through direct observation and structured consultations with the farm personnel. Milk samples were collected on three occasions, resulting in a total of 24 samples for laboratory analysis. The results showed that the milk's physical properties and chemical composition were within acceptable ranges, indicating generally adequate nutritional quality. Total coliform counts and thermotolerant bacteria ranged from 2.81×10^1 to 5.00×10^1 CFU/mL and 3.75×10^1 to 1.49×10^2 CFU/mL, respectively, and *Salmonella* sp. was not detected in any sample. However, a consistently high prevalence of presumptive *Staphylococcus aureus* and markedly elevated somatic cell counts were observed across all samples, indicating strong evidence of subclinical mastitis, with mean values of 6.81×10^4 CFU/mL and 2.83×10^6 cells/mL, respectively. These findings may indicate limitations in milking hygiene and udder health management. Furthermore, antibiotic residues were detected in 54.17% of the evaluated samples, suggesting potential non-compliance with prescribed veterinary withdrawal periods. Overall, these findings highlight important gaps in current milking hygiene and herd health management practices, which may compromise raw milk safety and quality. Although the single-farm scope of this study limits the broader generalizability of the insights across diverse dairy goat production systems, the evidence underscores that optimizing milking sanitation, refining mastitis monitoring, and enforcing the prudent administration of veterinary drugs are imperative to safeguard raw goat milk quality at the farm level.

Keywords: Milking hygiene, Goat milk quality, Mastitis, Antibiotic residues, Food safety

Introduction

Goat farming plays an important role in livestock production systems in southern Thailand, particularly in Muslim communities where cultural preferences, dietary practices, and the adaptability of goats to tropical environments support their widespread adoption under smallholder and semi-intensive systems. In the southern border provinces, including Narathiwat, goat production contributes not only to household income but also to local dairy supply chains, although challenges related to farm management, hygiene control, and product standardization persist (Department of Livestock Development, 2021; Limcharoen et al., 2020). Narathiwat Province was selected as the study area due to its active smallholder dairy goat production systems and its representation of typical management practices in southern Thailand. Goat milk is increasingly consumed as an alternative to cow milk due to its favorable nutritional composition, higher digestibility, and bioactive components that benefit specific consumer groups such as children, elderly individuals, and people with cow-milk intolerance (ALKaisy et al., 2023; Siddiqui et al., 2024). Consequently, demand for raw goat milk and value-added goat milk products has continued to expand in Thailand.

Despite its nutritional advantages, the safety and market potential of goat milk depend fundamentally on the quality of raw milk at the farm level. International studies consistently emphasize that hygienic milking practices,

udder health management, equipment sanitation, and post-milking handling are the primary determinants of raw milk quality, particularly in smallholder systems (Moraes et al., 2025). Inadequate hygiene during milking can facilitate microbial contamination, increase somatic cell counts, and compromise the suitability of milk for processing and human consumption. Variability in human behavior during milking, including differences among milkers and inconsistency in hygiene compliance, has been identified as a critical, but often underappreciated, factor influencing raw milk quality in small-scale dairy systems (Munera-Bedoya et al., 2017). However, few studies have simultaneously evaluated milking hygiene practices, milk microbiological quality, somatic cell counts, and antibiotic residues in smallholder dairy goat farms in Thailand.

In Thailand, raw goat milk quality is regulated under the Thai Agricultural Commodity and Food Standards (TACFS 6006 – 2008), which specifies minimum physicochemical requirements and microbiological criteria, including limits for total bacterial counts, somatic cell counts, and the absence of pathogenic microorganisms. In parallel, farm management and animal health practices are overseen by the Department of Livestock Development. These standards aim to ensure that raw milk entering the food chain is safe, wholesome, and suitable for further processing. However, compliance with these standards remains uneven, particularly among smallholder goat farms where resources, training, and routine monitoring are limited.

Among microbiological hazards associated with raw goat milk, *Staphylococcus aureus* is of particular concern. This pathogen is strongly associated with subclinical mastitis in dairy goats and can contaminate milk through infected udders, contaminated hands or towels, and inadequately cleaned or insufficiently dried milking equipment (Tibebu et al., 2026; Hassani et al., 2022). Persistent *S. aureus* contamination is often accompanied by elevated somatic cell counts (SCC), reflecting mammary gland inflammation that may not be apparent through clinical signs alone (Touaitia et al., 2025). High SCC not only reduces milk quality and shelf life but also adversely affects processing characteristics, posing challenges to producing fermented and heat-treated dairy products.

In addition to microbial risks, inappropriate use of veterinary drugs and failure to observe withdrawal periods may result in antibiotic residues in raw goat milk. Such residues pose public health concerns, interfere with dairy fermentation processes, and undermine consumer confidence in dairy products (Oladeji et al., 2025; Codex Alimentarius Commission, 2018). These issues highlight the need for integrated assessment of milking hygiene, udder health status, and compliance with national standards at the farm level. We hypothesized that gaps in milking hygiene practices may be associated with reduced raw goat milk quality at the farm level.

Accordingly, this study aimed to assess milking hygiene practices and their association with the physical, chemical, and microbiological quality of raw goat milk, including somatic cell counts and antibiotic residues, in a small-scale dairy goat farm in Narathiwat Province, southern Thailand. By linking observed milking behaviors with milk quality indicators and national standards, this case study seeks to identify critical hygiene gaps and provide practical insights to support improved milk safety and quality management in smallholder goat production systems.

Materials and Methods**Preliminary data collection**

General information was obtained through direct observation and interviews focusing on the milking process. This included the number of milkers, dairy goat breeds, number of lactating goats, milking equipment, milking area, milk yield, and milking duration. Milking hygiene practices were also recorded during routine milking using a structured observational checklist to describe hygiene-related practices at the farm.

Study Farm and Animal Management

The study was conducted at a small-scale dairy goat farm located in Narathiwat Province, southern Thailand. Eight lactating Saanen goats were included and remained in the study throughout the study period. The animals were fed a total mixed ration (TMR) containing 16% crude protein at approximately 8% of body weight once daily, with additional supplementation of Napier grass. Goats were housed in an elevated barn under a stall-fed system, and milking was performed manually by farm personnel. Routine farm management practices included regular cleaning of housing facilities, monitoring of animal health status, and implementation of standard milking hygiene procedures. The herd health program included routine health monitoring, vaccination, and parasite control under veterinary supervision.

Six milkers participated in the study and worked in rotating pairs during each sampling session. Before milking, the milking area was routinely prepared, and milkers performed hand hygiene. Udder preparation consisted of cleaning the udder and inner thighs with a cloth soaked in warm water, then drying with a separate clean cloth for each goat.

Milk was collected in stainless steel and plastic containers that were cleaned after each milking session. The milk storage area was separated from the animal housing and milking area, and cooling facilities were available for raw milk storage. Goats showing clinical signs of illness were managed according to veterinary recommendations, and milk from treated animals was withheld during the prescribed withdrawal period. Characteristics of the study farm and milking system are summarized in Table 1.

Table 1 Characteristics of the study farm

Parameter	Description
Location	Narathiwat Province
Breed	Saanen
Number of lactating goats	8
Housing system	Elevated stall-fed
Feeding	TMR (16% CP*) + Napier grass
Milking method	Hand milking
Number of milkers	6 (rotating pairs)
Sampling occasions	3

*CP= crude protein

Milking hygiene assessment

Milking hygiene at the dairy goat farm was evaluated using a structured on-farm checklist adapted from standard guidelines for small ruminant dairy production. The checklist covered key aspects of hygiene, including the condition of the milking environment, cleanliness of equipment and utensils, udder preparation before

milking, personal hygiene of milkers, milking procedures, post-milking udder care, handling and storage of raw milk, cold chain during transport, animal health management, and general farm sanitation. The hygiene assessment was conducted by a single trained researcher throughout the study period using the same standardized checklist during all farm visits. The use of a single evaluator ensured consistency in observation and data recording, and therefore, inter-observer bias was not applicable in this study.

Each item was assessed by direct observation during routine milking and recorded as either “observed” or “not observed.” No scoring system or weighting was applied, as the aim of this study was to provide a qualitative description of hygiene practices and identify potential hygiene gaps rather than to quantify or rank farm performance. Therefore, a binary checklist approach was considered appropriate for this exploratory single-farm case study design.

The checklist was used as a descriptive tool in this study, with a focus on identifying possible hygiene gaps that could affect milk quality. The results from the hygiene assessment were considered together with microbiological indicators, including total viable bacterial count, coliform bacteria, presumptive *S. aureus*, and somatic cell count, to provide contextual interpretation of milk quality findings in relation to observed milking hygiene practices. The full checklist is provided in Table 2.

Table 2 Milking hygiene assessment checklist used for on-farm evaluation

Category	Assessment item	Observation (Yes/No)	Remarks
1. General cleanliness	Milking area cleaned before milking	Yes / No	
	Milkers washed hands and wore clean clothing	Yes / No	
	Footbath provided before entering milking area	Yes / No	
	Separate area for changing or storing boots	Yes / No	
	Animals with mastitis milked last	Yes / No	
2. Pre-milking udder preparation	Udder, hind legs, flanks, and abdomen cleaned with disinfectant	Yes / No	
	One cloth used per animal for cleaning	Yes / No	
	Teats dried with a clean cloth	Yes / No	
	Mastitis screening performed (physical exam / CMT)	Yes / No	
3. Milking method	Hand milking	Observed / Not observed	
	Machine milking	Observed / Not observed	
4. Milker hygiene	Milker appeared healthy (no illness)	Yes / No	
	Hands and arms washed before each milking	Yes / No	
	No open wounds or abrasions on hands or arms	Yes / No	
5. Milking duration per animal	≥ 5 minutes	Observed / Not observed	
	5–10 minutes	Observed / Not observed	
	>10 minutes	Observed / Not observed	

Table 2 (Cont.)

Category	Assessment item	Observation (Yes/No)	Remarks
6. Post-milking udder management	Complete milk stripping performed	Yes / No	
	Teat dipping applied after milking	Yes / No	
	Fresh disinfectant used for each animal	Yes / No	
7. Milk collection containers	Stainless steel or food-grade plastic containers used	Yes / No	
	Containers resistant to corrosion	Yes / No	
	Containers cleaned after each use	Yes / No	
	Containers protected from insects, rodents, and dust	Yes / No	
8. Milk storage area	Cooling equipment available	Yes / No	
	Area protected from animals and pests	Yes / No	
	Storage area separated from milking and housing areas	Yes / No	
9. Cold chain and milk transport (< 4 °C)	Milk delivered within 30 minutes	Observed / Not observed	
	Milk delivered within 30–60 minutes	Observed / Not observed	
	Milk delivered within 1–2 hours	Observed / Not observed	
	Milk delivered after > 2 hours	Observed / Not observed	
10. Management of sick animals and drug use	Sick animals clearly identified and separated	Yes / No	
	Drug withdrawal periods followed	Yes / No	
11. Kid management and neonatal care	Adequate colostrum management practiced	Yes / No	
12. Feed management	Feed stored hygienically and protected from contamination	Yes / No	
13. Environmental and waste management	Proper manure and wastewater disposal	Yes / No	
14. Pest and vector control	Measures in place for insect and rodent control	Yes / No	
15. Health monitoring and vaccination	Annual health checks conducted	Yes / No	
	Vaccination program implemented	Yes / No	
16. Breeding and reproductive management	Controlled breeding and reproductive records maintained	Yes / No	

Observation was recorded as “Yes” when the practice was observed at the time of farm visit, and “No” when the practice was absent. The checklist was adapted from standard dairy hygiene guidelines for small ruminants.

Goat milk sample collection

Milk samples were collected from a dairy goat farm in Narathiwat Province, Thailand. Six milkers were involved in the milking process and worked in three pairs. Sampling was carried out on three separate occasions. At each time point, one pair of milkers collected raw milk samples (500 mL per goat) from eight goats, resulting in a total of 24 samples. All samples were kept at 4°C immediately after collection and transported under chill conditions for analysis of physical, chemical, and microbiological parameters.

Physical Quality Analysis of Raw Goat Milk

The physical quality of raw goat milk was assessed on general characteristics, including color, taste, and odor, using organoleptic evaluation. The presence of foreign matter, floating fat, and the cleanliness of milk containers (milk cans and lids) were also examined, with particular attention to possible milk stone deposits along container seams. All procedures followed the IDF Special Issue No. 9002, *Handbook on Milk Collection*.

Specific gravity was measured using a lactometer. Milk samples were first adjusted to 20°C and then transferred into a 50 mL graduated cylinder. The lactometer was gently placed into the milk without touching the cylinder walls to avoid reading errors. Values were read directly from the scale, with normal ranges between 1.028 and 1.034 at 20°C, following the method described by Kornacki et al. (2024).

Chemical Composition Analysis

The chemical composition of raw goat milk was analyzed at the Agricultural Development Center for Export (ADCET), Faculty of Agro-Industry, Prince of Songkla University, Hat Yai, Songkhla, Thailand. Parameters evaluated included specific gravity, protein, fat, solids-not-fat (SNF), moisture, ash, carbohydrate, and energy content. Protein, fat, SNF, density, lactose, water content, temperature, freezing point, salt content, and pH were determined using a Lactoscan milk analyzer. Moisture, ash, carbohydrate, and energy values were obtained from the laboratory analytical report provided by ADCET. The values obtained were compared with standards set by the Thai Agricultural Commodity and Food Standards (TACFS).

Milk stability was assessed using the alcohol test. Raw milk was mixed with 68% ethyl alcohol at a 1:1 ratio, gently agitated, and observed for protein precipitation. The appearance of suspended precipitates indicated increased acidity. Samples showing moderate to strong precipitation were further examined using the clot-on-boiling test, following the procedures described in *Handbook on Milk Collection in Warm Developing Countries* (International Dairy Federation, 1990).

The clot-on-boiling test was performed to evaluate heat stability and to confirm the alcohol test results. A well-mixed milk sample (5 mL) was transferred into a test tube and heated in a boiling water bath at 100°C for 5 minutes. Samples showing visible coagulation were considered unstable, typically corresponding to acidity levels of 0.2% lactic acid or higher, and therefore unsuitable for further processing.

Microbiological Analysis

The microbiological quality of raw goat milk was assessed using both qualitative and quantitative approaches. All samples were stored at 4°C and analyzed within 12 hours of collection.

The methylene blue reduction test (MBRT) was used as a rapid qualitative indicator of microbial activity. Ten milliliters of milk were transferred into sterile test tubes, and 1 mL of 1% methylene blue solution was added. The tubes were gently inverted, sealed, and incubated in a water bath at $37 \pm 5^\circ\text{C}$. Color changes were monitored at 30 minutes and then at hourly intervals up to 6 hours. Tubes showing decolorization were noted and removed at each time point. (Kornacki, 2024; Ahmadi, 2025) MBRT results were interpreted based on dye decolorization time. Samples were classified as excellent (>5 h), good (3–5 h), fair (1–3 h), and poor quality (<1 h), with shorter reduction times indicating higher microbial activity.

Total viable bacterial counts were determined using the standard plate count method. Milk samples were serially diluted (10^{-1} to 10^{-4}), and 0.1 mL of each dilution was spread in duplicate onto plate count agar. The plates were incubated at 30°C for 24 hours, colonies were counted and expressed as colony-forming units per milliliter (CFU/mL).

Coliform counts were measured as an indicator of hygienic conditions during milking and handling. Serial dilutions (10^{-1} to 10^{-4}) were prepared, and 0.1 mL aliquots were spread onto violet red bile lactose agar in duplicate. Plates were incubated at 35°C for 24 hours before colony enumeration based on ISO 4832:2006.

Thermotolerant bacteria were analyzed to assess the presence of heat-resistant microorganisms that may influence milk stability. Milk samples (5 mL) were heat-treated at 62.8°C for 30 minutes and then rapidly cooled to 10°C. Treated samples (0.1 mL) were plated in duplicate on plate count agar and incubated at 25–30°C for 24 hours. Colonies were counted and reported as CFU/mL based on the Standard Methods for the Examination of Dairy Products (Kornacki et al., 2024).

Pathogenic bacteria, including *S. aureus* and *Salmonella* spp., were also examined. For *S. aureus*, samples were serially diluted (up to 10^{-4}) in peptone saline, and 0.1 mL aliquots were spread onto Baird–Parker agar. Plates were incubated at 37°C for 24–48 hours, and typical black colonies with clear zones were counted following Tallent (2016). For *Salmonella* spp., 10 mL of milk was pre-enriched in 90 mL of peptone water and incubated at 37°C for 24 hours. An aliquot of the enrichment culture was then transferred onto modified semisolid Rappaport–Vassiliadis medium (MRSV) and incubated under the same conditions. Suspected samples were further confirmed on xylose lysine deoxycholate (XLD) agar according to ISO 6579:1993.

Antibiotic Residue Screening

Preliminary screening for antibiotic residues in raw goat milk was carried out using the yoghurt test. Plain yoghurt (150 g) was mixed with 150 mL of sterile distilled water and thoroughly homogenized. Milk samples (10 mL) were first heated at 100°C for 5 minutes and then cooled to 35–37°C. After cooling, 1 mL of the yoghurt solution was added to each sample and gently mixed. The mixtures were incubated in a water bath at 43°C for 3 hours. Coagulation of the milk was interpreted as the absence of antibiotic residues, while samples that remained liquid were considered to contain antimicrobial substances. The procedure followed the TACFS (TACFS 6407–2008).

Somatic Cell Count Analysis

Somatic cell count (SCC) was determined to assess udder health in raw goat milk. Somatic cells, mainly leukocytes and epithelial cells shed from the mammary gland, are commonly used as indicators of mastitis. SCC was measured using the direct microscopic method. A well-mixed milk sample (10 μ L) was evenly spread onto a clean glass slide and allowed to air-dry. The smear was then fixed in absolute methanol for 2 minutes. To remove fat residues, the slide was immersed in xylene for 5 minutes, followed by rinsing in absolute ethanol for 1 minute. It was then washed with distilled water and stained with methylene blue for 2 minutes. Excess stain was rinsed off gently, and the slide was left to dry completely. All somatic cell counts were performed by a single trained observer using a standardized direct microscopic counting procedure to ensure consistency and minimize observer-related variability. Somatic cells were counted under a light microscope, and SCC values were calculated using a microscopic factor (MF) based on the method described by the National Conference on Interstate Milk Shipments [NCIMS] (2024) as shown below:

$$\text{Somatic cell count (cells/mL)} = \text{Number of cells counted} \times \text{MF}$$

where the microscopic factor (MF) was approximately 318,471 (rounded to 320,000).

Statistical Analysis

Descriptive statistics were used to summarize the data and are presented as mean $\pm$ standard deviation (SD). Compliance with the Thai Agricultural Commodity and Food Standards (TACFS 6407–2008) was expressed as the percentage of samples meeting the criteria for somatic cell count and microbiological quality parameters. Given the exploratory single-farm case-study design and limited sample size ($n = 24$ milk samples from 8 goats), inferential statistical analyses such as correlation, regression, or Fisher's exact test were not performed, as the dataset was not suitable for hypothesis testing. Therefore, the analysis was limited to descriptive evaluation of milking hygiene practices and milk quality parameters.

Ethical statement

This study involved observational assessment of milking hygiene practices, interviews with farm personnel, and collection of milk samples during routine milking procedures. No experimental treatment, invasive sampling, animal restraint beyond normal farm management, or manipulation of animals was performed. Therefore, formal animal ethics approval was not required according to the institutional guidelines for non-invasive observational studies. Farm participation was voluntary, and permission to conduct the study was obtained from the farm owner before data collection. Interviews with farm personnel were conducted solely for the purpose of documenting routine farm management and milking practices, and no personal or sensitive information was collected. The study was conducted in accordance with the principles for the ethical use of animals in research and teaching and followed internationally recognized guidance for observational studies involving animals (National Research Council, 2011).

Results

Milking Performance During Sampling Sessions

Milk production and milking duration varied among the three sampling sessions (Table 3). Total milk yield ranged from 4.7 to 6.3 kg per session. Milk production per milker ranged from 2.1 to 3.6 kg, reflecting normal variation in milk yield among sampling occasions. The duration of milking sessions ranged from 24 to 40 minutes, with the longest duration recorded during Session 1 and the shortest during Session 2.

Table 3 Milk production and milking duration during the three sampling sessions

Descriptions	Milking session			mean $\pm$ SD
	Session 1	Session 2	Session 3	
Total of goat milk production (kg)	6.3	4.7	5.9	5.6 $\pm$ 0.8
Goat milk production per milker (kg)				
Milker I	2.9	2.6	3.6	3.0 $\pm$ 0.5
Milker II	3.4	2.1	2.3	2.6 $\pm$ 0.7
Total time spent milking (min)	40	24	32	32.0 $\pm$ 8.0

Values are presented as observed values per milking session.

Observed milking hygiene practices

The on-farm hygiene assessment identified that most basic milking hygiene practices were implemented during the study period. Both milkers routinely prepared the milking area before milking, used appropriate milk

collection containers, and maintained basic personal hygiene. However, several deficiencies were observed. Routine mastitis screening, including physical examination of the udder or the use of the California Mastitis Test (CMT), was not performed. Post-milking teat dipping was applied inconsistently, and disinfectant solutions were not routinely replaced between animals. In addition, goats suspected of mastitis were not consistently milked last.

With regard to milk handling and storage, cooling facilities were available and milk was transported within an appropriate time frame. Nevertheless, several supporting biosecurity measures were absent, including footbaths, designated boot-changing areas, and adequate pest-control measures. Overall, the findings indicate that while fundamental hygiene practices were generally followed, important gaps remained in mastitis prevention and cross-contamination control.

Preliminary Quality Assessment of Raw Goat Milk

Based on organoleptic evaluation, all raw goat milk samples (24/24, 100%) met the acceptable criteria for physical characteristics, including color, odor, and taste. The samples showed a white to creamy-white appearance, a natural odor, and a slightly sweet taste, in line with the standards of the TACFS (TACFS, 2008).

The specific gravity of the milk, measured using a lactometer across the three sampling sessions, was 1.032 ± 0.002 , 1.032 ± 0.001 , and 1.032 ± 0.001 , respectively. These values were all above the minimum standard of 1.028 at 20°C, indicating normal milk density.

Chemical composition analysis indicated that the average protein content was 3.95% (w/w), with all samples meeting the standard and classified as premium quality. The average fat content was 3.83% (w/w), with 66.67% of samples (16/24) meeting the standard and categorized as good quality. The mean solids-not-fat (SNF) content was 12.72%, and all samples complied with the standard, corresponding to the good quality category. Additional compositional parameters, including moisture, ash, carbohydrate, and energy content, are summarized in Table 4.

Table 4 Physicochemical composition of raw goat milk across three sampling sessions

Parameter	Milking session			Overall mean $\pm$ SD	TACFS standard
	Session 1	Session 2	Session 3		
Specific gravity (Sp.Gr.)	1.032 ± 0.002	1.032 ± 0.001	1.032 ± 0.001	1.032 ± 0.001	1.028 – 1.034
Protein (%w/w)	3.91 ± 0.01	4.21 ± 0.08	3.73 ± 0.01	3.95 ± 0.03	≥ 3.00
Fat (%w/w)	3.54 ± 0.10	2.03 ± 0.02	4.18 ± 0.01	3.83 ± 0.04	≥ 3.20
Solid not fat (%w/w)	13.07 ± 0.12	11.23 ± 0.02	13.85 ± 0.01	12.72 ± 0.05	≥ 8.25
Moisture (%w/w)	86.00 ± 0.19	86.69 ± 0.15	86.73 ± 0.13	86.47 ± 0.16	NS
Ash (%w/w)	0.81 ± 0.02	0.81 ± 0.01	0.86 ± 0.01	0.83 ± 0.01	NS
Carbohydrate (g/100 g)	5.04	6.95	4.65	5.55	NS
Energy (Kcal/100 mL)	67.69	62.95	71.14	67.26	NS

Values are presented as mean $\pm$ SD. Each milking session represents one sampling occasion (n = 8 goats per session).

TACFS = Thai Agricultural Commodity and Food Standards (TAS 6006–2008). Parameters for moisture, ash, carbohydrate, and energy are not specified in the standard.

NS = Not specified

Protein Stability of Raw Goat Milk

Protein stability of raw goat milk was assessed using the alcohol test with 68% ethyl alcohol. Of the 24 samples analyzed, 14 (58.33%) showed fine flake precipitation, corresponding to an approximate acidity of 0.19% and classified as normal-quality milk. The remaining 10 samples (41.67%) exhibited medium flake

precipitation, with an estimated acidity of around 0.23%, indicating borderline quality according to the TACFS (TACFS 6006–2008). It is worth noting that goat milk generally contains a higher proportion of whey proteins than cow milk, which may affect heat stability and contribute to variation in alcohol test results. For this reason, the clot-on-boiling (COB) test was used for confirmation, as recommended by TACFS. No coagulation was observed in any of the samples during the COB test, indicating good protein stability and suggesting that the milk remained suitable for further processing. Representative results of both tests are shown in Fig. 1.

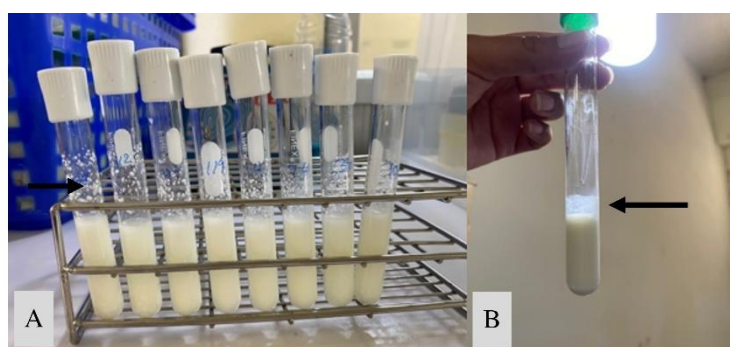


Figure 1 Representative results of protein stability tests in raw goat milk: (A) Alcohol test showing flake precipitation after mixing with 68% ethyl alcohol and (B) clot-on-boiling (COB) test showing no coagulation after heating. Arrows indicate the observed reaction areas

Microbiological Quality of Raw Goat Milk

Microbiological quality of raw goat milk was evaluated using both qualitative and quantitative methods, including the methylene blue reduction test (MBRT), standard plate count (SPC), coliform count, thermophilic bacteria count, and screening for selected pathogens (*Staphylococcus aureus* and *Salmonella* spp.).

The MBRT results varied across sampling sessions. In the first sampling session, three out of eight samples (3/8; 37.5%) showed methylene blue decolorization within 4 hours, indicating reduction times within the fair (1–3 h) range or approaching the lower end of the good (3–5 h) range, depending on the exact decolorization time. The remaining samples did not show decolorization within this period. In the second sampling session, none of the 8 samples (0/8; 0%) decolorized within 4 hours, indicating that all samples had reduction times exceeding 4 hours. These samples therefore fell within the good (3–5 h) to excellent (>5 h) categories. During the third sampling session, only one sample (1/8; 12.5%) decolorized methylene blue within the observation period, while the remaining samples (7/8; 87.5%) retained the blue color throughout the incubation. This indicates that most samples had reduction times longer than the observed period, corresponding to good to excellent categories.

Total viable bacterial counts, determined by the SPC method, indicated that most samples were within acceptable limits. Seventeen samples (70.83%) were classified as very good quality, and six samples (25.0%) as good quality. Only one sample (4.17%), collected during the first session, exceeded the recommended limit ($> 2 \times 10^5$ CFU/mL). The overall mean total viable count was 1.21×10^6 CFU/mL (Table 5, Fig. 2).

Coliform counts ranged from 28.1 to 31.9 CFU/mL across sampling sessions, and all samples met the standard requirement ($< 1 \times 10^3$ CFU/mL). Thermophilic bacteria were also within acceptable limits, with all

samples showing counts below 1×10^3 CFU/mL, indicating low levels of heat-resistant contamination (Table 5, Fig. 2).

In contrast, colonies presumptively identified as *S. aureus* were detected in all samples (24/24, 100%), with mean counts exceeding the TACFS-defined acceptable limits. This finding suggests potential issues related to udder health or milking hygiene. Typical colonies were observed as smooth, circular, convex, grayish to black with clear zones on Baird–Parker agar. *Salmonella* spp. was not detected in any sample (Table 5).

Table 5 Microbiological quality parameters of raw goat milk across three sampling sessions

parameter (CFU/mL)	Milking session			TACFS standard
	Session 1	Session 2	Session 3	
Total viable count (TVC)	1.21×10^6	9.96×10^4	1.54×10^4	$\leq 5 \times 10^5$
Total coliform count	2.81×10^1	5.00×10^1	3.19×10^1	Not specified
Thermotolerant bacteria count	1.49×10^2	1.25×10^2	3.75×10^1	Not specified
Presumptive <i>S. aureus</i>	6.81×10^4	7.64×10^3	7.50×10^3	Not specified
<i>Salmonella</i> sp.	ND	ND	ND	Not detected

*Values are presented as mean counts (CFU/mL) per sampling session.

TACFS = Thai Agricultural Commodity and Food Standards (TAS 6006–2008). ND = Not detected. No TACFS criteria are specified for total coliform count, thermotolerant bacteria count, or presumptive *S. aureus*

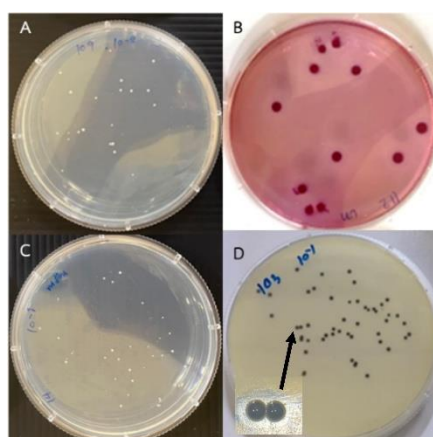


Figure 2 Representative microbiological cultures obtained from raw goat milk samples. (A) Total viable count agar on plate count agar (PCA), (B) Total coliform bacteria on violet red bile lactose agar (VRBA), (C) thermotolerant bacteria on plate count agar (PCA), and (D) presumptive *S. aureus* colonies on Baird–Parker agar (BPA). The arrow indicates a representative presumptive *S. aureus* colony, and the inset shows an enlarged view of the characteristic colony morphology

Somatic cell counts of raw goat milk

Somatic cell count (SCC) in raw goat milk varied considerably across the three sampling sessions. Based on the criteria of the TACFS (TACFS, 2008), only two samples (2/24, 8.33%) were classified as good quality. Three samples (3/24, 12.50%) fell within the acceptable range, with SCC values between 1.0×10^6 and 1.5×10^6 cells/mL. In contrast, most samples (19/24, 79.16%) exceeded the recommended limit, with SCC values above 1.5×10^6 cells/mL.

Antibiotic Residues in Raw Goat Milk

The presence of antibiotic residues in raw goat milk was screened using the yogurt test. In this assay, coagulation indicates the absence of antibiotic residues, whereas a lack of curd formation suggests the presence of antimicrobial substances. As a qualitative method, the test does not provide information on residue concentration. Among the 24 samples analyzed, 11 (45.83%) showed normal coagulation, indicating no detectable residues. In contrast, 13 samples (54.17%) remained in liquid form, suggesting the presence of antibiotic residues.

Discussion

The management framework of the investigated dairy goat farm represents a well-regulated, small-scale production environment, which aligns with the overall satisfactory quality of the raw goat milk recorded during this research. The use of a total mixed ration with adequate crude protein, together with stall-fed management in an elevated housing system, likely supported stable milk composition across sampling sessions. Nutritional management is widely recognized as an important factor influencing both milk yield and composition in dairy goats (ALKaisy et al., 2023; Siddiqui et al., 2024).

Basic hygiene practices were also in place. Routine cleaning of the milking area, handwashing by milkers, and the use of separate cloths for udder preparation are all measures known to reduce microbial contamination during manual milking (Requejo et al., 2024). This is reflected in the acceptable organoleptic properties and specific gravity values observed in all samples, indicating compliance with fundamental quality standards, and no indications of sample dilution were detected. The relatively high protein and solids-not-fat contents further support the overall nutritional quality of the milk. These findings suggest that the basic farm management and milking hygiene practices observed in the present study were generally adequate to maintain the physicochemical quality of raw goat milk. Proper udder preparation, routine cleaning of the milking area, and the use of clean milking equipment likely contributed to preserving milk composition and preventing quality deterioration. Some variation in fat content was observed, which is not unusual in goat milk and may be influenced by individual animals, stage of lactation, and short-term changes in feeding or milking conditions (ALKaisy et al., 2023; Moraes et al., 2025).

Results from the alcohol test suggested that a portion of the samples fell into a borderline category. However, this should be interpreted with caution. Goat milk differs from cow milk in protein composition, particularly in having a lower α s1-casein content and a higher proportion of whey proteins, which can affect ethanol stability (Siddiqui et al., 2024; Moraes et al., 2025). Reduced stability has been reported even in milk of acceptable quality. In this study, the absence of coagulation in the clot-on-boiling test indicates that the milk remained stable under heat treatment, supporting its suitability for further processing. These findings highlight the need to consider multiple tests when evaluating protein stability in goat milk (Requejo et al., 20124).

Microbiological results showed that total viable bacterial counts were generally within acceptable limits, although an increase was observed during the first sampling session. This may reflect temporary lapses in hygiene, such as insufficient equipment cleaning or incomplete pre-milking udder preparation. Raw milk readily supports microbial growth, and even minor deviations in practice can lead to increased bacterial counts (Hoving-Bolink et al., 2023). In contrast, coliform counts remained low, suggesting limited fecal contamination and generally

acceptable sanitary conditions during milking and handling (Martin et al., 2016). Similarly, low thermophilic bacteria indicate that the milk was suitable for further processing. These findings suggest that routine cleaning and handling procedures were generally effective in controlling overall bacterial contamination. Nevertheless, the microbiological profile also indicates that some hygiene-related risks remained present within the production system.

The coexistence of generally acceptable hygiene practices with persistent detection of presumptive *S. aureus* and elevated somatic cell counts suggests that basic sanitation measures alone may not be sufficient to ensure optimal milk quality. While routine cleaning and handwashing may reduce environmental contamination, these practices may have limited effectiveness in controlling mastitis-associated pathogen transmission. In dairy goats, infected mammary glands can serve as a continuous source of bacterial contamination even when general farm hygiene is acceptable. Therefore, deficiencies in udder health monitoring and mastitis control may have contributed to the observed microbiological findings despite the implementation of routine hygiene measures.

The MBRT results were consistent with the microbiological data. Shorter methylene blue reduction times were observed in the first sampling session, corresponding to markedly higher total viable bacterial counts compared with subsequent sessions. In contrast, longer reduction times or absence of decolorization in later sessions aligned with substantially lower bacterial loads, as shown by TVC values. These findings indicate that MBRT reflects differences in overall microbial activity among sampling sessions.

Despite these generally favorable indicators, presumptive *S. aureus* was detected in all samples, pointing to specific weaknesses in milking hygiene. This organism is commonly associated with contamination from handlers, inadequately cleaned equipment, or insufficient drying of teats and utensils (Hassani et al., 2022; Mogotu et al., 2022). Moist conditions on teat surfaces or in containers may facilitate its survival and spread. In addition, *S. aureus* is a well-known cause of caprine mastitis and can be transmitted between animals through shared equipment or improperly managed udder preparation (Buckley & Hayman, 2025; Girma & Tamir, 2022).

A high proportion of samples also showed elevated somatic cell counts, indicating widespread mammary gland inflammation, most likely subclinical mastitis. This condition is common in dairy goats and often occurs without obvious clinical signs, yet it can significantly affect milk quality (Touaitia et al., 2025). The consistent presence of *S. aureus* supports a link between pathogen infection and increased SCC, as infection triggers an immune response leading to leukocyte infiltration into the milk (Abebe et al., 2020; Touaitia et al., 2025). Management factors may have contributed as well, including incomplete teat drying, lack of routine screening using tools such as the California Mastitis Test, and limited segregation of affected animals (Fadillah et al., 2023). These management deficiencies may have facilitated the persistence and transmission of *S. aureus* within the herd. In particular, the absence of routine mastitis screening may have allowed subclinical infections to remain undetected, enabling infected animals to act as continuous reservoirs of contamination during milking. The elevated SCC observed in many samples further supports the likelihood of ongoing mammary gland inflammation associated with subclinical mastitis. Therefore, the high prevalence of presumptive *S. aureus* in this study may reflect not only shortcomings in milking hygiene but also insufficient udder health management and mastitis control practices at the farm level. However, as this study was conducted on a single farm with a limited number of animals, the findings should be interpreted as exploratory.

More than half of the samples tested positive for antibiotic residues, suggesting challenges in drug use management at the farm level. In small-scale systems, antibiotics are sometimes used with limited veterinary

oversight, increasing the risk of not fully observing withdrawal periods (Oladeji et al., 2025). Although regulations require compliance, practical constraints may lead to residues being present in milk. Possible contributing factors include inadequate treatment records, insufficient monitoring of treated animals, failure to segregate milk from animals undergoing treatment, and limited awareness or implementation of recommended withdrawal periods. These challenges are commonly reported in smallholder dairy systems and may increase the likelihood of antibiotic residues entering the milk supply. It should also be noted that the yogurt test used here is a qualitative screening method and does not provide quantitative information on residue concentrations. Furthermore, it cannot identify specific classes of antibiotics and may be influenced by factors affecting starter culture activity (Kebede et al., 2014). The presence of antibiotic residues is of concern not only for public health, due to risks such as allergic reactions and antimicrobial resistance, but also for dairy processing, as residues can interfere with fermentation (Codex Alimentarius Commission, 2018; Manyi-Loh et al., 2018; Sachi et al., 2019; Oladeji et al., 2025; Senata et al., 2025). Nevertheless, the relatively high proportion of positive samples observed in this study indicates that antibiotic residue contamination may represent an important food safety concern at the farm level. These findings highlight the need for improved veterinary supervision, stricter adherence to recommended withdrawal periods, and routine residue monitoring. Such measures are essential to protect consumer health, support dairy product quality, and maintain public confidence in raw goat milk production. Future studies should employ more sensitive confirmatory analytical methods, such as high-performance liquid chromatography (HPLC) or liquid chromatography–tandem mass spectrometry (LC-MS/MS), to accurately identify and quantify antibiotic residues in raw goat milk. A strength of this study is the integration of on-farm observational data with comprehensive milk quality analyses, allowing a holistic assessment of production practices and milk safety. These findings are particularly relevant for smallholder dairy goat systems where improvements in routine hygiene and mastitis control can have immediate effects on milk quality.

Overall, while basic hygiene practices were implemented at the farm, the findings point to gaps in mastitis control, consistency of milking hygiene, and antibiotic use management. Strengthening udder health monitoring, improving hygiene practices, and ensuring proper veterinary oversight would help further improve the quality and safety of raw goat milk in small-scale production systems.

Study Limitations

To guide future research directions, specific characteristics of this study can be viewed as valuable foundational benchmarks. First, this study focused on a single dairy goat enterprise, establishing a deep baseline understanding that lays the groundwork for expanding multi-farm investigations across broader production systems. Second, the hygiene assessment provided a detailed descriptive overview, successfully establishing the qualitative prerequisites necessary for future targeted quantitative modeling of management-to-quality variables. Third, antibiotic residues were evaluated using the yogurt test, which is a screening method and does not identify specific antibiotic classes or residue concentrations. Finally, the identification of presumptive *S. aureus* isolates serves as a critical biological indicator, paving the way for upcoming studies to apply definitive molecular confirmation. Future studies involving multiple farms, larger sample sizes, and more advanced analytical methods are recommended to strengthen the generalizability and robustness of the findings.

Conclusion and Suggestions

This study showed that the studied small-scale dairy goat farm applied basic farm management and milking hygiene practices that supported acceptable physicochemical and organoleptic quality of raw goat milk. All samples met national standards for specific gravity, protein content, and solids-not-fat, indicating satisfactory compositional quality. However, microbiological analysis revealed critical challenges, particularly the consistent presence of presumptive *S. aureus*, elevated somatic cell counts, and occasional increases in total viable bacterial counts, suggesting a high prevalence of subclinical mastitis. In addition, the detection of antibiotic residues in a substantial proportion of samples reflects inadequate compliance with recommended withdrawal periods. Overall, the findings demonstrate that acceptable physicochemical quality does not necessarily guarantee microbiological safety. Persistent detection of presumptive *S. aureus*, elevated somatic cell counts, and antibiotic residues highlight the need for improved udder health management, stricter milking hygiene practices, and better oversight of veterinary drug use in smallholder dairy goat production systems. Routine screening for subclinical mastitis using the California Mastitis Test, strict adherence to antibiotic withdrawal periods, and regular farmer training on milking hygiene are recommended. Future studies should include a larger number of farms, intervention-based evaluations of milking hygiene improvement programs, advanced analytical methods for antibiotic residue detection, and confirmatory testing of mastitis-associated pathogens to improve the generalizability and robustness of the findings.

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Author Contributions

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Conflict of Interests

The authors declare no conflict of interest.

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Declaration of Generative AI and AI-assisted Technologies

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