

Research Article

Seasonal Variation in Milk Quality and Somatic Cell Count of Friesian Crossbred Cows in Southern Highlands, Tanzania

Charles Mpemba^{1,*} , Selemani Masola¹ , Edwin Chang'a¹, Lokoo Mwaipopo¹ , Mwemezi Kabululu² , Wilson Wilson³ , Eliamon Lyatuu⁴ 

¹Tanzania Livestock Research Institute, Mbeya, Tanzania

²Tanzania Livestock Research Institute, Mpwapwa, Tanzania

³The Nelson Mandela African Institute of Science and Technology, Arusha, Tanzania

⁴International Livestock Research Institute, Dar Es Salaam, Tanzania

Abstract

Seasonal variations in environmental conditions and forage availability can substantially influence milk composition and udder health, yet information from dairy production systems in the Southern Highlands of Tanzania remains limited. This study evaluated the effects of season on physicochemical milk quality parameters and somatic cell count (SCC) in Friesian crossbred cows managed under a semi-intensive production system at the Tanzania Livestock Research Institute (TALIRI) Uyole Dairy Farm. A total of 640 milk samples were collected from 20 cows during the rainy and dry seasons of 2024 and analyzed using an ultrasonic Lactoscan milk analyzer. Linear mixed-effects models were used to assess the effect of season while accounting for repeated measurements on individual cows. Milk fat content and freezing point were significantly higher during the dry season, whereas electrical conductivity and log-transformed SCC were significantly higher during the rainy season, indicating poorer udder health and reduced milk hygiene during periods of increased moisture. Protein, lactose, and solids-not-fat contents did not differ significantly between seasons. These findings demonstrate that seasonal environmental conditions substantially influence milk quality and udder health in semi-intensive dairy systems and highlight the importance of season-specific management strategies to improve milk quality and reduce the risk of subclinical mastitis in tropical dairy production.

Keywords

Milk Quality, Somatic Cell, Seasonal, Mastitis, Tanzania

1. Introduction

Milk is one of the most important foods of animal origin, providing high-quality protein, essential fatty acids, lactose, vitamins and minerals necessary for human nutrition and health.

Globally, the quality of raw milk is a critical determinant of public health, dairy productivity, and economic returns to farmers and processors [1, 2]. In Tanzania, milk consumption is

*Correspondence: Charles Mpemba (charlesmpemba@gmail.com)

Received: 6 July 2026; Accepted: 22 July 2026; Published: 29 October 2026



Copyright: © The Author(s), 2026. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

about 2.4 to 3 billion liters per year and is expected to increase to 4 billion liters due to rapid urbanization, an increase in the human population and income [3, 4]. Despite this high demand for milk, only 60-70% of the total milk produced within the country is collected, processed and marketed due to inadequate and inefficient collection and processing infrastructure, which compromises milk quality along the value chain [5, 6]. To narrow the gap between the current milk production and consumption, the dairy sector's capacity, which outsources its supply from about 1.2 million dairy cows, highlights the critical need for better dairy infrastructure, improving productivity, milk quality and safety management [7, 8].

Milk quality is shaped by a complex interaction of biological, managerial and environmental factors, including animal breed, stage of lactation, feeding system, udder health, milking hygiene, environmental conditions and post-harvest handling practices [9-11]. Physicochemical parameters, including fat, protein, lactose, solid-not-fat (SNF), density and freezing point, are widely used indicators of milk composition and authenticity and play a critical role in determining its nutritional value and processing performance, particularly in the manufacture of fermented products, cheese and butter [12].

Deviations from normal physicochemical ranges may indicate adulteration, inadequate feeding regimes, or physiological stress in dairy cows. The freezing point of milk is widely used as an indicator of added water, while density and SNF content provide complementary information on milk solids and authenticity [12]. In addition to compositional parameters, hygienic and health-related indicators such as somatic cell count (SCC) and electrical conductivity are essential for assessing raw milk quality. Somatic cells are primarily leukocytes that increase in milk in response to intramammary infections such as mastitis. Elevated SCC is associated with reduced milk yield, altered milk composition, decreased shelf life and inferior processing performance [13, 14]. Electrical conductivity and salt concentration are also closely linked to udder health, as inflammation alters the permeability of the mammary epithelium, leading to increased sodium and chloride ions in milk [15, 16].

Rapid and reliable analytical techniques are increasingly required for routine milk quality monitoring at farm and milk collection centers. The Lactoscan milk analyser is a widely used ultrasonic-based instrument capable of simultaneously measuring multiple milk quality parameters within a short time. Previous studies have demonstrated its applicability for routine assessment of fat, protein, lactose, SNF, density, freezing point and conductivity in raw milk, particularly in resource-limited settings where conventional laboratory analyses may be costly or time-consuming [10, 17].

Despite the importance of the dairy sector in Tanzania, particularly in the Southern Highlands where dairy production is expanding, there is limited published information on the combined effects of seasonal variation on physicochemical milk quality and udder health indicators under semi-intensive production systems. Previous studies have largely focused on

milk production, value chain challenges, or isolated milk quality parameters, while comprehensive evaluations integrating physicochemical characteristics and somatic cell count in Friesian crossbred cows remain scarce. Furthermore, evidence from institutional dairy farms, such as the Tanzania Livestock Research Institute (TALIRI) Uyole Dairy Farm, is limited despite their important role in dairy research and technology dissemination. This lack of locally generated evidence constrains the development of season-specific management strategies to improve milk quality and reduce the prevalence of subclinical mastitis. Therefore, this study evaluated the effects of seasonal variation on physicochemical milk quality parameters and somatic cell count in Friesian crossbred cows managed under a semi-intensive dairy production system at TALIRI Uyole in the Southern Highlands of Tanzania.

2. Materials and Methods

2.1. Study Area

The study was conducted at TALIRI Uyole Dairy Farm, situated between 08.92°44' – 08.92°11' S and 33.54°53' – 33.53°63' E, at an elevation of 1824 m above sea level; in Mbeya region, in the Southern Highlands of Tanzania. The region experiences a mean annual temperature of 23 °C; mean monthly temperatures range from a minimum of 6 °C in July to a maximum of 26 °C in December. The area receives an average annual precipitation of 1200 mm, characterized by a unimodal rainfall pattern occurring between November and May.

2.2. Farm Management and Animals

The study was conducted in March and April 2024 (rainy season) and July and August 2024 (dry season), using Friesian crossbred dairy cattle at the TALIRI Uyole Dairy Farm. The animals were managed under a semi-intensive system, grazing daily from 07:30h to 15:30h on mainly natural grasses and partly on established pastures consisting of Rhodes grass (*Chloris gayana*) and Greenleaf Desmodium (*Desmodium intortum*). In addition to grazing, each animal was supplemented with 1kg of concentrate feed daily. Potable water was provided ad libitum via troughs located within the paddocks.

2.3. Milk Sample Collection and Handling

A total of 20 Friesian crossbred cows in early to mid-lactation (2nd to 4th parity) were included in the study and monitored during both the rainy season (March–April 2024) and the dry season (July–August 2024). The same cows were followed throughout the study to allow repeated measurements across seasons.

Milk samples were collected twice per week for four consecutive weeks during each season. On each sampling day, milk was collected from each cow at both the morning (05:00 h) and evening (16:00 h) milking sessions. Thus, each cow

contributed 16 milk samples per season (2 sampling days $\times$ 2 milkings per day $\times$ 4 weeks), resulting in 320 milk samples per season (20 cows $\times$ 16 samples) and a total of 640 milk samples across the two seasons.

Before sample collection, the first three streams of foremilk were discarded to minimize contamination. Approximately 50 mL of composite milk, representing the total milk yield from each cow at each milking session, was collected into sterile food-grade plastic containers. Immediately after collection, milk temperature was measured using a calibrated digital thermometer. Samples were protected from direct sunlight and transported in insulated cool boxes maintained at approximately 4 °C to the laboratory. All laboratory analyses were initiated within 2 hours of sample collection to preserve the physicochemical characteristics and ensure sample integrity.

2.4. Biological/Physiological and Physicochemical Analysis using Ultrasonic Milk Analyzer

Milk quality parameters were determined using a Lactoscan (Milkotronic Ltd, Bulgaria), an automated ultrasonic milk analyzer. The instrument was reset daily using standard reference solutions provided by the manufacturer. Prior to analysis, milk samples were gently inverted to ensure homogeneity and allowed to equilibrate to the analyzer's required operating temperature (20 $\pm$ 1 °C) to ensure measurement accuracy. The analyzer provided direct quantification of the following parameters: fat (%), SNF (%), protein (%), lactose (%), and salts (%). Additionally, biological or physiological indicators of milk quality particularly SCC (cells/mL) and physical properties including freezing point (°C) and electrical conductivity (mS/cm) were recorded. To minimize cross-contamination between samples, the analyzer was automatically rinsed with distilled water and a specialized alkaline cleaning solution after every five measurements. All samples were analyzed in triplicate, and the mean values were used for subsequent statistical evaluation.

2.5. Quality Control and Data Management

All analytical procedures were performed in accordance with the standard operating protocols provided by the equipment manufacturer. To ensure measurement precision and prevent sample carry-over or cross-contamination, the ultrasonic analyzer was automatically flushed with deionized water and a specialized cleaning solution (LactoClean) between each sample. Data were digitally recorded and cross-verified for consistency prior to being exported for statistical analysis.

2.6. Ethical Statement

The researchers did not perform any invasive procedures or experimental manipulations on live animals. Milk samples

were obtained from the cows' milking routine, scheduled farm milking operations. As the study involved the use of non-invasive collection of animal products within standard agricultural practices, formal ethical approval was not required.

2.7. Statistical Analysis

Statistical analyses were performed using R software (version 4.5.1; R Foundation for Statistical Computing, Vienna, Austria). Descriptive statistics were summarized as estimated marginal means (EMMs) $\pm$ standard error (SE). Seasonal differences in physicochemical milk quality parameters were evaluated using *linear mixed-effects models* fitted with the *lme4* package. Season, week of sampling, and milking time (morning or evening) were included as fixed effects, while cow identity was included as a random effect to account for repeated measurements obtained from the same cows. Somatic cell count (SCC) data were *log10-transformed* before analysis to satisfy model assumptions of normality and homoscedasticity. Estimated marginal means and pairwise comparisons were computed using the *emmeans* package. Statistical significance was declared at $P < 0.05$.

3. Results

3.1. Physicochemical Composition of Milk

The physicochemical profile of raw milk showed significant seasonal variations across several key parameters (Table 1). The fat content was significantly higher ($P = 0.01$) during the dry season (3.22 $\pm$ 0.20%) compared to the rainy season (2.64 $\pm$ 0.17%). Similarly, the freezing point was significantly lower (more depressed) during the dry season (-0.47 $\pm$ 0.06 °C) than in the rainy season (-0.43 $\pm$ 0.07 °C) at $P = 0.03$. While protein, lactose, and SNF percentages were numerically higher during the dry season, these differences did not reach statistical significance ($P > 0.05$), suggesting a relatively stable synthesized milk composition across seasons at TALIRI Uyole.

3.2. Physical Properties and Milk Hygiene

The electrical conductivity was significantly elevated during the rainy season (6.39 $\pm$ 0.02 mS/cm) compared to the dry season (5.78 $\pm$ 0.25 mS/cm $P = 0.02$) (Table 1). This trend in conductivity aligned with the SCC, which was significantly higher ($P = 0.01$) during the rainy season ($\text{Log}_{10}(\text{SCC}) = 5.67 \pm 0.05$) than in the dry season ($\text{Log}_{10}(\text{SCC}) = 5.55 \pm 0.04$). Furthermore, milk temperature at the time of collection was significantly higher during the rainy season (25.5 $\pm$ 0.6 °C; $P = 0.03$). Moreover, the fat percentage content was significantly higher during the dry season compared to the rainy season ($P = 0.01$).

Table 1. Estimated Least Square Means $\pm$ Standard Error ($\pm$ SE) of physicochemical milk quality parameters by season obtained from linear mixed-effects models.

Parameter	Rainy Season (March-April)	Dry Season (July-August)	P-Value
Temperature ($^{\circ}$ C)	25.5 $\pm$ 0.6	24.4 $\pm$ 0.5	0.03
Fat (%)	2.64 $\pm$ 0.17	3.22 $\pm$ 0.20	0.01
SNF (%)	7.45 $\pm$ 0.14	7.60 $\pm$ 0.16	0.12
Protein (%)	3.12 $\pm$ 0.10	3.23 $\pm$ 0.12	0.07
Lactose (%)	4.22 $\pm$ 0.14	4.28 $\pm$ 0.15	0.31
Freezing Point ($^{\circ}$ C)	-0.43 $\pm$ 0.07	-0.47 $\pm$ 0.06	0.03
Conductivity (mS/cm)	6.39 $\pm$ 0.02	5.78 $\pm$ 0.25	0.02
Salt (%)	0.41 $\pm$ 0.11	0.35 $\pm$ 0.09	0.05
Log ₁₀ (SCC)	5.67 $\pm$ 0.05	5.55 $\pm$ 0.04	0.01

Values are estimated least square means ($\pm$ SE) from linear mixed-effects models with season as a fixed effect and cow identity as a random effect. Somatic cell count (SCC) was analyzed after log₁₀ transformation. Statistical significance was declared at $P < 0.05$.

3.3. Distribution of SCC

The distribution of SCC across the sampled population is summarized in Table 2. Only 15% ($n=3$) of the cows maintained an SCC below 100,000 cells/mL, indicating excellent

udder health. However, a significant proportion of the herd (35%, $n=7$) exhibited SCC levels exceeding 400,000 cells/mL, suggesting a high prevalence of subclinical mastitis. Collectively, 65% of the cows exceeded the 200,000 cells/mL threshold, which is widely recognized as the physiological limit for a healthy mammary gland.

Table 2. Distribution of SCC among the study cows ($N=20$).

SCC (Cell/mL)	Intrepretation	Number of Cows (n)	Percentages (%)
< 100,000	Healthy /Normal	3	15%
100,000–200,000	Threshold / Low Risk	4	20%
200,000–400,000	Subclinical Mastitis	6	30%
> 400,000	Significant Infection	7	35%

3.4. Seasonal Distribution of SCC

The seasonal distribution of SCC categories is illustrated in Figure 1. During the rainy season, a substantial proportion of the sampled population (45%) exhibited SCC levels indicative

of significant infection ($> 400,000$ cells/mL). In contrast, the dry season showed a higher prevalence of cows in the healthy ($< 100,000$ cells/mL) and early infection (100,000–200,000 cells/mL) categories, collectively representing 45% of the herd compared to only 25% during the rainy season.

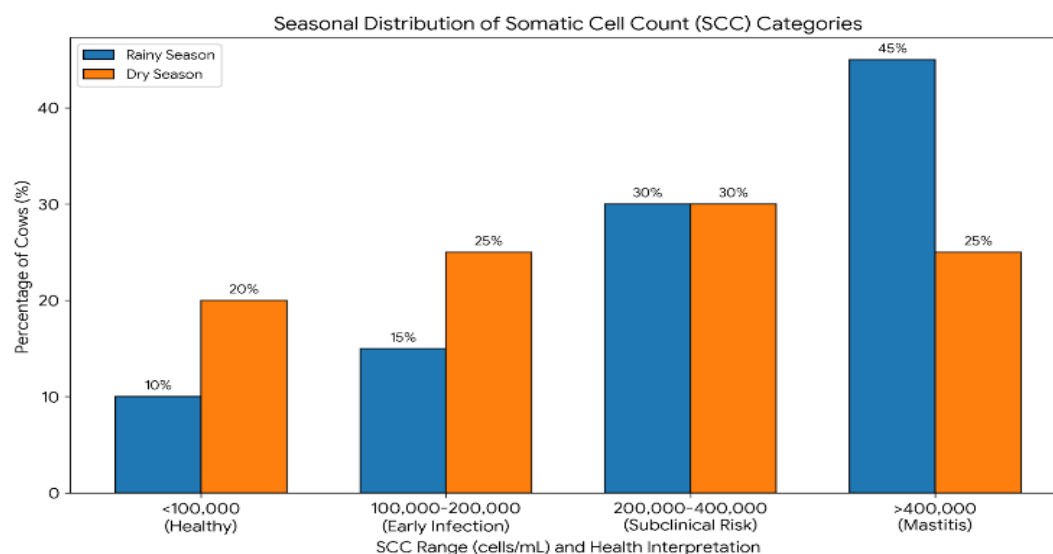


Figure 1. Distribution of cows across somatic cell count categories during the rainy and dry seasons. Percentages are based on the 20 cows sampled in each season.

4. Discussion

4.1. Physicochemical Composition of Milk

Seasonal variation significantly influenced several physicochemical characteristics of milk produced by Friesian cross-bred cows managed under a semi-intensive dairy production system in the Southern Highlands of Tanzania. The linear mixed-effects model demonstrated significant seasonal effects on milk fat, freezing point, electrical conductivity, milk temperature, and log-transformed somatic cell count, whereas solids-not-fat (SNF), protein, and lactose contents remained relatively stable. These findings indicate that seasonal environmental conditions primarily affected milk constituents associated with nutritional status and udder health rather than components under tighter physiological regulation.

Milk temperature was significantly higher during the rainy season than during the dry season. This difference is likely associated with higher ambient humidity and reduced efficiency of heat dissipation during the rainy season, resulting in slightly elevated body and milk temperatures. Elevated milk temperature may also accelerate bacterial multiplication when milk is not cooled immediately after milking, thereby compromising milk quality. Similar observations have been reported in tropical dairy production systems, where elevated environmental temperature and humidity increase bacterial proliferation and accelerate deterioration of raw milk quality when cooling is delayed [18, 19].

Milk fat content was significantly higher during the dry season. This observation is most likely attributable to seasonal changes in feeding management and rumen fermentation. During periods of limited pasture availability, dairy cows are

commonly supplemented with conserved forages and concentrate feeds to maintain nutrient intake. Such dietary adjustments increase the proportion of structural carbohydrates in the diet, promoting ruminal acetate production through fiber fermentation. Acetate is the principal precursor for the synthesis of short- and medium-chain fatty acids in the mammary gland and therefore plays a central role in milk fat synthesis [20, 21]. Similar relationships between feeding management and milk fat concentration have been reported in Ethiopian dairy herds, where nutritional management significantly influenced milk composition across production systems [22].

In contrast, seasonal differences in SNF, protein, and lactose contents were not statistically significant. These milk components are generally regulated more tightly than milk fat because they are closely associated with osmotic regulation and mammary gland metabolism [9]. The relatively stable values observed throughout the study suggest that the feeding regime at TALIRI Uyole maintained adequate nutrient supply despite seasonal fluctuations in forage availability. Comparable findings have been reported in Ethiopian dairy farms, where breed, parity, and lactation stage explained a greater proportion of variation in protein and lactose content than seasonal effects [22].

Milk freezing point was significantly lower during the dry season. This parameter is primarily determined by the concentration of dissolved constituents, particularly lactose and mineral salts, and therefore reflects changes in the osmotic pressure of milk rather than direct environmental effects [9, 23]. Although the seasonal difference observed in the present study was relatively small, it suggests subtle changes in milk composition associated with seasonal feeding practices and water intake, both of which have been reported to influence the freezing point of milk [23]. Routine monitoring of milk freezing point remains important for quality assurance because it

serves as a reliable indicator of milk authenticity and the possible addition of water during milk handling or processing [24, 25].

Electrical conductivity was significantly higher during the rainy season, indicating reduced udder health during this period. Increased rainfall and humidity create favorable conditions for the proliferation of environmental mastitis pathogens, while muddy housing conditions increase bacterial contamination of the teat surface [26, 27]. During intramammary infection, inflammatory damage to mammary epithelial cells disrupts the integrity of the blood–milk barrier, allowing sodium and chloride ions to diffuse into milk while potassium concentration decreases, thereby increasing milk electrical conductivity [28, 29]. The positive association between elevated electrical conductivity and somatic cell count observed in this study is consistent with recent findings from Ethiopian dairy herds, where increased somatic cell scores were moderately correlated with electrical conductivity and reduced milk quality [22].

The slight increase in milk salt concentration during the rainy season further supports the occurrence of inflammatory changes within the mammary gland. Increased sodium and chloride concentrations in milk are characteristic responses to compromised mammary epithelial integrity during subclinical mastitis [28]. Together, the observed changes in electrical conductivity, salt concentration, and somatic cell count suggest that udder health was more adversely affected during the rainy season than during the dry season.

4.2. Effect of Season on Somatic Cell Count

Season had a significant effect on log-transformed somatic cell count ($\log_{10}$ SCC), with higher values observed during the rainy season than during the dry season. The use of a linear mixed-effects model strengthened this inference by accounting for repeated measurements obtained from the same cows throughout the study, thereby providing more reliable estimates of seasonal effects than analyses assuming independent observations.

The higher somatic cell count observed during the rainy season is consistent with previous studies conducted in Tanzania. For example, [30] reported a high prevalence of subclinical mastitis among smallholder dairy farms in Mvomero and Njombe districts, demonstrating that poor udder hygiene and environmental contamination substantially compromise milk quality. Similarly, [31] observed that mastitis remains one of the major constraints affecting milk quality in traditional dairy systems in Tanzania, with bacterial contamination and poor hygienic practices contributing to reduced milk quality. These findings support the present study, suggesting that increased rainfall, muddy housing conditions, and greater environmental exposure during the rainy season increase the likelihood of intramammary infections, leading to elevated somatic cell counts and reduced milk quality.

The elevated SCC recorded during the rainy season is most

likely attributable to increased exposure of dairy cows to environmental mastitis pathogens under wet and humid conditions. Rainfall promotes the accumulation of mud and manure in animal resting and walking areas, increasing bacterial contamination of the teat surface and the risk of intramammary infection [32]. Once infection occurs, leukocytes migrate into the mammary gland as part of the innate immune response, resulting in increased SCC. Consequently, elevated SCC is widely recognized as one of the most reliable indicators of subclinical mastitis and declining milk quality.

The concurrent increase in SCC and electrical conductivity observed in this study further supports the presence of inflammatory changes within the mammary gland during the rainy season. Similar relationships have been reported in Tanzania, Kenya, Ethiopia, Rwanda, and Uganda, where higher SCC and increased prevalence of subclinical mastitis have consistently been associated with periods of increased rainfall and poor environmental hygiene [31, 33, 34]. These findings emphasize the importance of maintaining clean housing conditions, improving drainage around dairy facilities, and implementing effective teat hygiene before and after milking to reduce seasonal mastitis risk.

4.3. Implications for Dairy Management in Tropical Production Systems

From a practical perspective, the observed seasonal differences indicate that dairy farmers in the Southern Highlands of Tanzania should adopt season-specific management strategies to maintain milk quality throughout the year. During the rainy season, priority should be given to improving housing sanitation, drainage around dairy facilities, and pre- and post-milking teat hygiene to reduce exposure to environmental mastitis pathogens. Strategic monitoring of electrical conductivity and somatic cell count could facilitate early detection of subclinical mastitis before clinical signs become evident. During the dry season, maintaining adequate nutritional supplementation is essential to sustain milk composition, particularly milk fat content, despite seasonal reductions in pasture availability. Such interventions are likely to improve milk quality, reduce economic losses associated with mastitis, and enhance the sustainability of semi-intensive dairy production systems in Tanzania.

Overall, this study provides locally generated evidence that seasonal variation affects both milk composition and udder health in Friesian crossbred cows managed under semi-intensive tropical production systems. These findings contribute to the limited body of literature available for Tanzania and provide practical information to support dairy farmers, extension services, and policymakers in developing targeted interventions aimed at improving milk quality, animal health, and the sustainability of dairy production under changing climatic conditions.

This study was conducted using 20 Friesian crossbred cows

from a single research farm, which may limit the generalizability of the findings to other dairy production systems in Tanzania. Furthermore, observations were limited to one rainy and one dry season within a single year. Future studies involving multiple farms, larger sample sizes, and longer monitoring periods across different agroecological zones are recommended to validate and extend these findings. The findings of this study also highlight the potential value of implementing Hazard Analysis and Critical Control Point (HACCP)-based management practices in semi-intensive dairy production systems. Seasonal identification of critical control points, such as milking hygiene, udder sanitation, milk cooling, and housing cleanliness, may help reduce microbial contamination and the incidence of subclinical mastitis. Adopting HACCP principles alongside routine monitoring of physicochemical milk quality parameters and somatic cell count could improve milk safety, product quality, and animal health throughout both the rainy and dry seasons.

5. Conclusion

Overall, this study provides important baseline evidence on the influence of seasonal variation on physicochemical milk quality and udder health in Friesian crossbred cows managed under a semi-intensive dairy production system in the Southern Highlands of Tanzania. By applying linear mixed-effects models that accounted for repeated measurements from individual cows, the study provides robust estimates of seasonal effects on milk quality traits. The findings contribute to the limited body of published information on seasonal milk quality in Tanzania and emphasize the need for integrated nutritional and udder health management strategies tailored to tropical production systems. These results may assist dairy farmers, extension services, and policymakers in developing evidence-based interventions aimed at improving milk quality, reducing subclinical mastitis, and enhancing the productivity and sustainability of the Tanzanian dairy sector.

Abbreviations

TALIRI	Tanzania Livestock Research Institute
SNF	Solids-not-fat
SCC	Somatic Cell Count
SE	Standard Error
EC	Electrical Conductivity
HACCP	Hazard Analysis and Critical Control Point

Acknowledgments

The authors wish to express their sincere gratitude to the technical staff of TALIRI Uyole for their invaluable support during the implementation of this study. Special appreciation is extended to Wakuru Shadrack, Lazaro Malendeja (Livestock Field Officers) and Frank Choga (Livestock Officer) for

their dedicated assistance in milk sample collection, handling, and laboratory analysis. Their technical expertise and commitment to ensuring high-quality data were instrumental to the successful completion of this research.

The authors also gratefully acknowledge Nicodem Mwamboja (Farm Manager) at TALIRI Uyole Dairy Farm, for his support in facilitating access to animals, farm operations, and logistical arrangements throughout the study period.

The authors further acknowledge the support provided by the International Livestock Research Institute (ILRI) through the Tropical Dairy Genetic Gains (TDGG) Programme for providing the Lactoscan milk analyzer and technical assistance on its operation and use during the study. This support greatly contributed to the successful analysis of milk quality parameters and the overall implementation of the research.

Author Contributions

Charles Mpemba: Data curation, Formal Analysis, Methodology, Writing – original draft, Writing – review & editing

Selemani Masola: Data curation, Validation, Visualization, Writing – review & editing

Edwin Chang'a: Methodology, Writing – review & editing

Lokoo Mwaipopo: Data curation, Methodology, Writing – review & editing

Mwemezi Kabululu: Data curation, Methodology, Writing – review & editing

Wilson Wilson: Data curation, Formal Analysis, Writing – review & editing

Eliamon Lyatuu: Data curation, Methodology, Project administration, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

References

- [1] Murphy S. C., Martin N. H., Barbano D. M. and Wiedmann M. (2016). Influence of raw milk quality on processed dairy products: How do raw milk quality test results relate to product quality and yield? *Journal of Dairy Science* 99 (12): 10128-10149. <https://doi.org/10.3168/jds.2016-11172>
- [2] Smith, N., W., Fletcher, A., J., Hill, J. P. and McNabb, W. C. (2022). Modeling the Contribution of Milk to Global Nutrition. *Front Nutr.* <https://doi.org/10.3389/fnut.2021.716100>
- [3] United Republic of Tanzania (URT). (2018). National Bureau of Statistics: Livestock Sector Analysis. Ministry of Livestock and Fisheries.
- [4] Tanzania Food and Nutrition Centre (TFNC). (2019). Tanzania food and nutrition security analysis report. Ministry of Health, Community Development, Gender, Elderly and Children.

- [5] Kimario, J. J., Shija, D. S. and Ngasapa, D. (2016). Evaluation of milk quality and safety along the dairy value chain in Tanzania: A case of the Eastern Zone. *International Journal of Livestock Production*, 7(12), 120–128.
<https://doi.org/10.5897/IJLP2016.0315>
- [6] Mlozi, M. R., Shayo, H. E. and Maleko, G. D. (2018). Constraints and opportunities for smallholder dairy farmers in the milk value chain: A case of Mbeya and Njombe regions, Tanzania. *Tanzania Journal of Agricultural Sciences*, 17 (2), 85–96.
- [7] Kurwijila, L. R. and Bennett, A. (2010). Dairy development institutions in East Africa. Lessons learned and options. Food and Agriculture Organization of the United Nations, Rome, Italy.
- [8] Ledo, J., Hettinga, K. A., Bijman, J. and Luning, P. A. (2019). Persistent challenges in safety and hygiene control practices in emerging dairy chains: The case of Tanzania. *Food Control*, 105, 164–173.
- [9] Walstra, P., Wouters, J. T. M. and Geurts, T. J. (2006). Dairy science and technology (2nd ed.). CRC Press.
- [10] International Dairy Federation [IDF]. (2011). Technical Guide on Milk Quality and Payment Systems. IDF Bulletin 448/2011.
- [11] Fox, P. F., and McSweeney, P. L. H. (2015). Advanced dairy chemistry: Volume 1A: Proteins – Basic aspects (4th ed.). Springer.
- [12] Meena, S., Debnath, P. P., Ranvir, S. G. and Rai, D. C. (2023). Physicochemical Characteristics of Milk. In: Goyal MR, Ranvir S, & Malik JA (Eds) *The Chemistry of Milk and Milk Products*, 1st ed, pp 109 – 130, Apple Academic Press Inc.
<https://doi.org/10.1201/9781003340706-8>
- [13] Ermetin, O., Kul, E. and Okuyucu, I. C. (2024). The relationship of somatic cell count with milk yield and composition in different stages of lactation in Holstein cows. *Veterinary Archives*, 94(1): 21–32
<https://doi.org/10.24099/vet.arhiv.2213>
- [14] Guliński, P. and Salamończyk, E. (2025). Somatic cells – causes and consequences of their varying presence in cow milk. *Animal Science Papers and Reports*, 43(4): 429–462.
<https://doi.org/10.2478/aspr-2025-0028>
- [15] Sramek, Á., Bodnár, Á., Póti, P. and Pajor, F. (2018). The effect of udder health on mineral concentrations and fatty acid composition of alpine goat milk. *Animal Science Papers and Reports*, 36(4): 383–392.
- [16] Roca, A., Muelas, R., Alejandro, M., Romero, G. and Dáz, J. R. (2023). Effect of the Onset of Intramammary Infection on the Electrical Conductivity of Ewe's Milk and Study of Various Algorithms for Its On-Line Detection. *Animals*, 13, 1808.
<https://doi.org/10.3390/ani13111808>
- [17] O'Connell, A., Ruegg, P. L., Jordan, K., O'Brien, B. and Gleeson, D. (2017). The effect of storage temperature and duration on the microbial quality of raw milk. *Journal of Dairy Science*, 100(2), 1–12.
<https://doi.org/10.3168/jds.2016-11584>
- [18] Ramírez-Rivera, E. J., Rodríguez-Miranda, J., Huerta-Mora, I. R., Cárdenas-Cágal, A., & Juárez-Barrientos, J. M. (2019). Tropical milk production systems and milk quality: A review. *Tropical Animal Health and Production*, 51(6), 1295–1305.
<https://doi.org/10.1007/s11250-019-01922-1>
- [19] Jayarao, B. M., & Wolfgang, D. R. (2004). Bulk-tank milk analysis: A useful tool for improving milk quality and herd udder health. *Veterinary Clinics of North America: Food Animal Practice*, 20(3), 485–513.
<https://doi.org/10.1016/j.cvfa.2004.06.017>
- [20] Bauman, D. E., & Griinari, J. M. (2003). Nutritional regulation of milk fat synthesis. *Annual Review of Nutrition*, 23, 203–227.
- [21] Palmquist, D. L., Beaulieu, A. D., & Barbano, D. M. (1993). Feed and animal factors influencing milk fat composition. *Journal of Dairy Science*, 76(6), 1753–1771.
- [22] Chernet, T. F., Okeyo, A. M., Meseret, S., Negussie, E., Mrode, R., Takekegn G. M., Edea, Z., Gebreyohanes, G., Ekine-Dzi-venu, C., Tera, A. and Tessema, T. S. (2024). Milk somatic cell count, composition and yield of multi-breed dairy cattle in Ethiopia. *Cogent Food Agriculture* 10(1).
https://doi.org/10.1080/23311932.2024.2421957?urlappend=%3Futm_source%3Dresearchgate.net%26utm_medium%3Darticle
- [23] Shipe, W. F. (1959). The freezing point of milk: A review. *Journal of Dairy Science*, 42(11), 1745–1762.
[https://doi.org/10.3168/jds.S0022-0302\(59\)90805-7](https://doi.org/10.3168/jds.S0022-0302(59)90805-7)
- [24] Poonia, A., Jha, A., Sharma, R., Singh, H. B., Rai, A. K., & Sharma, N. (2017). Detection of adulteration in milk: A review. *International Journal of Dairy Technology*, 70(1), 23–42.
<https://doi.org/10.1111/1471-0307.12274>
- [25] Barnard, S. E. (1977). Freezing points and milk adulteration. *Journal of Food Protection*, 40(4), 272–273.
<https://doi.org/10.4315/0362-028X-40.4.272>
- [26] Bradley, A. J. (2002). Bovine mastitis: An evolving disease. *The Veterinary Journal*, 164(2), 116–128.
<https://doi.org/10.1053/tvjl.2002.0742>
- [27] Hogan, J. S., & Smith, K. L. (2012). Managing environmental mastitis. *Veterinary Clinics of North America: Food Animal Practice*, 28(2), 217–224.
- [28] Kitchen, B. J. (1981). Review of the progress of dairy science: Bovine mastitis: Milk compositional changes and related diagnostic tests. *Journal of Dairy Research*, 48(1), 167–188.
- [29] Norberg, E. (2005). Electrical conductivity of milk as a predictor of mastitis—A review. *Livestock Production Science*, 96(2–3), 129–139.
<https://doi.org/10.1016/j.livprodsci.2005.01.011>
- [30] Mdegela, R. H., Ryoba, R., Karimuribo, E. D., Phiri, E. J., Løken, T., Reksen, O., Mtengeti, E. and Urio N. A. (2009). Prevalence of clinical and subclinical mastitis and quality of milk on smallholder dairy farms in Tanzania. *J S Afr Vet Assoc*. 2009 Sep; 80(3): 163–8.
<https://doi.org/10.4102/jsava.v80i3.195>

- [31] Karimuribo, E. D., Kusiluka, L. J., Mdegela, R. H., Kapaga, A. M., Sindato, C. and Kambarage, D. M. (2005). Studies on mastitis, milk quality and health risks associated with consumption of milk from pastoral herds in Dodoma and Morogoro regions, Tanzania. *J. Vet. Sci.* (2005), 6(3), 213–221.
- [32] Ruegg, P. L. (2017). A 100-year review: Mastitis detection, management, and prevention. *Journal of Dairy Science*, 100(12), 10381–10397.
<https://doi.org/10.3168/jds.2017-13023>
- [33] Mpatswenumugabo, J. P., Bebora, L. C., Gitao, G. C., Mobegi, V. A., Iraguha, B., Kamana, O., & Shumbusho, B. (2017). Prevalence of subclinical mastitis and distribution of pathogens in dairy farms in Rwanda. *Journal of Veterinary Medicine*.
- [34] Sharma, N., Singh, N. K. and Bhadwal, M. S. (2011). Relationship of somatic cell count and mastitis: An overview. *Asian-Australasian Journal of Animal Sciences*, 24(3), 429–438.
<https://doi.org/10.5713/ajas.2011.10233>