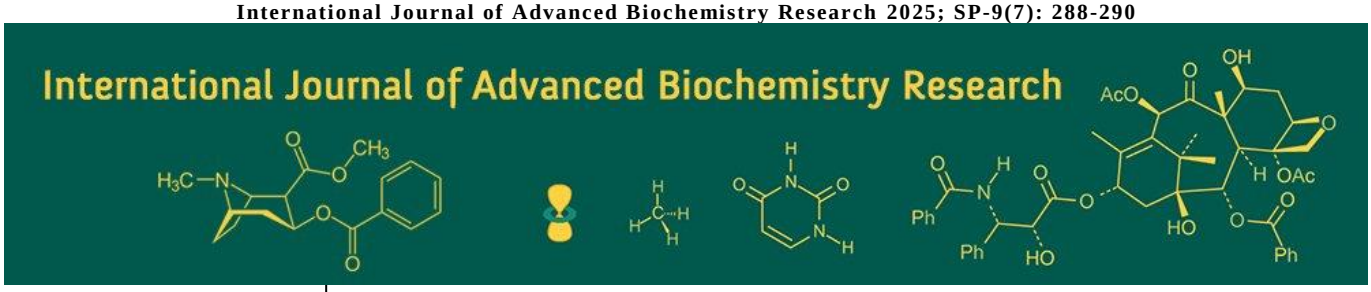

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2025; SP-9(7): 288-290
www.biochemjournal.com
Received: 15-05-2025
Accepted: 18-06-2025

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Milk composition and its seasonal variation in Theni Malaimadu cattle under traditional management practices in Tamil Nadu, India

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DOI: https://www.doi.org/10.33545/26174693.2025.v9.i7Sd.4822

Abstract
Background: Theni Malaimadu cattle, an indigenous breed of Tamil Nadu, India, are traditionally maintained for agriculture purposes and cultural events. Milk production in this breed remains poorly documented due to semi-wild rearing practices and the prioritization of calf suckling.
Methods: A total of 53 cows were evaluated for initial milk yield across four seasons. Additionally, milk samples from 30 cows were analysed for fat, solids-not-fat (SNF), and protein content across early, mid, and late lactation stages. Seasonal variations were assessed using principal component analysis (PCA) and discriminant analysis.
Results: The average initial milk yield remained low in all seasons, ranging from 0.443±0.022 L in summer to 0.491±0.021 L in winter, highlighting the breed's semi-wild traits and traditional management practices. Fat percentage increased significantly from early (2.18±0.77%) to late lactation (4.82±0.33%). Protein levels showed a modest rise across lactation stages. Principal component analysis showed winter had the highest impact on milk composition, accounting for 48.56% of variation.
Conclusion: This study provides the first systematic insights into milk yield and composition of Theni Malaimadu cattle under traditional management. The findings underscore low initial milk yield and significant lactation-stage impacts on fat content, with indications of seasonal effects, particularly during winter. These insights serve as baseline data for conservation and selective breeding strategies targeting this important indigenous breed.

Keywords: Theni Malaimadu cattle, indigenous breeds, milk yield, milk composition, seasonal variation, traditional management

Introduction
Indigenous cattle breeds in India constitute a vital genetic resource, sustaining traditional farming and cultural practices. Theni Malaimadu cattle, native to the Theni district in Tamil Nadu, are particularly significant for their adaptability to local agro-climatic conditions and their roles in cultural events like rekla and jallikattu (Richard Jagatheesan *et al.*, 2024) [4]. Despite this cultural and ecological importance, scientific information regarding their milk production and composition is scant due to their semi-wild temperament and traditional management practices that prioritize calf consumption over milking (Satheeshkumar *et al.*, 2024a; Priyadharsini *et al.*, 2024) [9, 5].
Understanding milk yield and compositional characteristics in indigenous breeds like Theni Malaimadu is crucial for evaluating production potential, preserving genetic diversity, and planning sustainable breeding programs (FAO, 2013; Bernabucci *et al.*, 2002) [2, 1]. Studies in other native breeds, such as Gir and Sahiwal, have documented significant seasonal and lactation-stage variations in milk composition (Gajbhiye *et al.*, 2019; Parmar *et al.*, 2020) [3, 7]. However, comparable data for Theni Malaimadu cattle under traditional conditions remain lacking (Satheeshkumar *et al.*, 2024b) [10]. Additionally, concerns have arisen regarding declining indigenous bull populations and associated ecological, economic, and cultural implications, highlighting the importance of comprehensive studies on indigenous cattle populations (Satheeshkumar *et al.*, 2024b) [10]. The socio-economic role of Theni Malaimadu cattle for local farmers further underscores the need for such research (Priyadharsini *et al.*, 2024) [8].

The present study aimed to investigate the initial milk yield and milk compositional traits of Theni Malaimadu cattle across different seasons and lactation stages. Advanced statistical analyses, including PCA and discriminant analysis, were employed to characterize seasonal impacts and provide baseline data for breed conservation and selective breeding initiatives.

Materials and Methods

Study Area and Breed Context

The study was conducted in Theni district, Tamil Nadu, where Theni Malaimadu cattle are reared under semi-wild condition and extensive systems. The animals primarily serve purposes such as draught work, manure production, and cultural sports rather than dairy production (Satheeshkumar *et al.*, 2024a) [4, 8-10]. Traditional management involves extensive grazing with minimal supplementation, and routine milking is uncommon due to the practice of reserving milk for calves (Priyadharsini *et al.*, 2024) [8].

Animal Selection and Sampling

Fifty-three lactating Theni Malaimadu cows were selected through local veterinary outreach and farmer engagement. Initial milk yield was measured immediately after parturition or within few days of post calving across four seasons: summer, winter, monsoon, and rainy. The same animals were followed where feasible across seasons, though practical limitations existed due to extensive management systems. For milk composition analysis, 30 cows were further selected based on accessibility and owner consent. From each cow, 50 ml milk samples were collected during early (pre), mid (middle), and late (post) lactation. Samples were transported under sterile conditions to the laboratory for analysis.

Milk Yield Measurement

Initial milk yield, recorded immediately or within few days of post-calving depending on the availability, was measured in liters using calibrated measuring equipment. This measurement represents early lactation only and does not reflect entire lactation yields due to minimal milking practices under traditional systems.

Analytical Procedures

Milk samples were analysed for fat, SNF, and protein content using an ultrasonic milk analyser (EKO model), calibrated before each session (Gajbhiye *et al.*, 2019) [3].

Statistical Analysis

Descriptive statistics (Mean ± SE) were calculated for all milk yield and composition data using SPSS (Version 21). Seasonal impacts on milk traits were evaluated using PCA to identify major sources of variability. Correlations between seasons were assessed, and discriminant analysis was applied to explore differentiation among seasons based on milk composition (Bernabucci *et al.*, 2002) [1]. Ethical guidelines were strictly followed, with owner consent obtained for all sampling activities.

Results and Discussion

Milk Yield of Malaimadu cattle

The initial milk yield recorded in Theni Malaimadu cattle remained low across all seasons, confirming their traditional role as sporting animals rather than primary milk producers. As shown in Table 1, the mean initial milk yield varied only slightly between seasons, with the highest yield observed in winter (0.491±0.021 L) and the lowest in summer (0.443±0.022 L). The slightly higher yield during winter could be linked to better forage availability and reduced thermal stress, which is consistent with observations in other indigenous breeds where cooler seasons support improved energy balance and milk secretion (Bernabucci *et al.*, 2002; Kabil *et al.*, 2015) [1, 6]. However, the overall milk yield remained below commercial dairy standards, reflecting the breed's primary role as a sports and manure production rather than a milk producer (Satheeshkumar *et al.*, 2024a; Priyadharsini *et al.*, 2024) [4, 9, 10, 8].

Table 1: Mean initial milk yield (L) of Theni Malaimadu cattle across seasons.

Season	Mean Initial Milk Yield (L) (Mean ± SE)
Summer	0.443±0.022
Winter	0.491±0.021
Monsoon	0.491±0.010
Rainy	0.481±0.019

Milk Composition across Lactation stages

In terms of milk composition, fat content increased progressively across lactation stages, rising from 2.18±0.77% in early lactation to 4.82±0.33% in late lactation (Table 2). This trend aligns with earlier studies indicating that energy reserves stabilize in later lactation, allowing higher fat synthesis. The increase in fat in late lactation is likely due to reduced milk volume and energy mobilization (Jozwik *et al.*, 2012) [5]. Comparable trends have been reported in Gir and Sahiwal breeds (Gajbhiye *et al.*, 2019; Parmar *et al.*, 2020) [3, 7].

Table 2: Milk composition across lactation stages (n = 10 per stage)

Parameter	Pre (Mean ± SE)	Middle (Mean ± SE)	Post (Mean ± SE)
Fat (%)	2.18±0.77	4.31±0.51	4.82±0.33
SNF (%)	8.28±0.04	8.29±0.03	8.33±0.04
Protein (%)	3.46±0.13	3.54±0.20	3.61±0.20

Solids-not-fat (SNF) levels remained quite stable across lactation, ranging between 8.28±0.04% and 8.33±0.04% (Table 2). Protein content also exhibited modest variation, increasing slightly from 3.46±0.13% in early lactation to 3.61±0.20% in late lactation. Such consistency in SNF and protein suggests that, although the quantity of milk is low, its compositional quality is comparable to other indigenous breeds (Singh, 2019) [11].

Seasonal Variation and Multivariate Analysis

The relationship between seasons was explored through correlation and PCA, as summarized in Table 3 and Table 4.

Table 3: Correlations among seasons for transformed milk variables.

Season	Summer	Winter	Monsoon	Rainy
Summer	1.000	0.389	0.093	0.240
Winter	0.389	1.000	0.223	0.674
Monsoon	0.093	0.223	1.000	0.033
Rainy	0.240	0.674	0.033	1.000

Table 4: Eigenvalues from PCA of milk composition across seasons.

Dimension	Eigenvalue	% of Variance
1	1.942	48.560
2	0.980	43.225
3	0.794	45.892
4	0.283	—

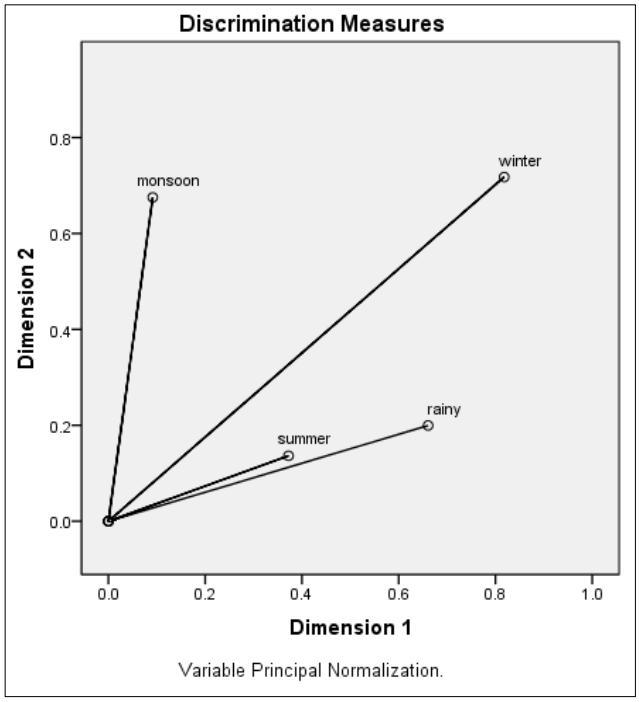

Fig 1: Discrimination plot showing the relative contribution of seasonal factors (summer, monsoon, rainy, winter) to variability in milk yield of Theni Malaimadu cattle based on principal component analysis.

PCA results revealed that Dimension 1 explained 48.56% of the variability in milk parameters, with winter season exerting higher discrimination measures (0.818). Higher correlation between winter and rainy seasons suggests similar environmental influences such as cooler temperatures and greater forage availability. Such seasonal effects have been reported in other breeds, where winter milk generally shows higher fat and protein due to better feeding conditions and lower heat stress (Bernabucci *et al.*, 2002; Kabil *et al.*, 2015) [1, 6].

However, interpretation of seasonal effects is constrained in this study due to small sample size and the breed's management practices, which limit consistent sampling across seasons.

Conclusion

This study offers the first detailed insights into the milk yield and composition of Theni Malaimadu cattle under traditional management systems. Despite low milk yields, the breed exhibits stable milk quality and resilience across all seasons, with fat content increasing notably in late lactation. Seasonal influences, particularly during winter, reflect subtle environmental effects rather than major effect, underscoring the breed's adaptability to diverse climatic conditions. These findings provide a valuable baseline for conservation and breeding programmes. Future work should explore genetic factors contributing to climate resilience and identify strategies to sustainably improve production while preserving the unique traits of this indigenous breed.

Conflict of Interest

The authors declare no conflict of interest.

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