Dynamics of somatic cell count in dairy cattle across lactation stages: Implications for udder health and milk quality

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Abstract
This study explores the dynamics of somatic cell count (SCC) across various stages of lactation in dairy cattle, an essential indicator of milk quality and udder health. By employing a longitudinal observational approach, we monitored the SCC in a cohort of dairy cows across distinct lactation phases: colostrum, early, mid, and late lactation. Our analysis revealed significant fluctuations in SCC, with the highest counts observed during the colostrum phase, attributed to the physiological changes post-parturition. A gradual decrease in SCC was noted as lactation progressed into the early phase, indicating the stabilization of udder health. However, mid-lactation showed a variable pattern, influenced by factors such as environmental stress and feed quality. Interestingly, a noticeable increase in SCC was observed during the late lactation phase, possibly due to the cumulative effect of lactational stress and the onset of involution processes. These findings underscore the critical importance of phase-specific management practices to maintain optimal udder health and milk quality throughout the lactation cycle.

Keywords: Somatic cell count, mastitis, udder health, milk quality

Introduction
The somatic cell count (SCC) in milk serves as a key indicator for assessing the health of the mammary gland in dairy animals, with elevated SCC levels being associated with mastitis, an inflammatory response in the udder tissue. By employing a longitudinal observational approach, we monitored the SCC in a cohort of dairy cows across distinct lactation phases: colostrum, early, mid, and late lactation. Our analysis revealed significant fluctuations in SCC, with the highest counts observed during the colostrum phase, attributed to the physiological changes post-parturition. A gradual decrease in SCC was noted as lactation progressed into the early phase, indicating the stabilization of udder health. However, mid-lactation showed a variable pattern, influenced by factors such as environmental stress and feed quality. Interestingly, a noticeable increase in SCC was observed during the late lactation phase, possibly due to the cumulative effect of lactational stress and the onset of involution processes. These findings underscore the critical importance of phase-specific management practices to maintain optimal udder health and milk quality throughout the lactation cycle.

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Furthermore, research has demonstrated the role of specific immune cells and inflammatory markers in the context of mastitis and its effect on SCC. For instance, studies have shown that mastitis is associated with increased levels of free fatty acids, somatic cell count, and interleukin-8 concentrations in milk, suggesting that these components may serve as biomarkers for mammary gland inflammation (Hunt et al., 2013) [6]. The implementation of effective mastitis control programs and adherence to best management practices are essential for maintaining optimal udder health and minimizing SCC levels in dairy herds. These practices include regular monitoring of SCC, proper milking hygiene, prompt identification and treatment of infected animals, and effective dry cow management. By understanding the lactation phase-specific changes in SCC and the underlying factors contributing to these variations, dairy farmers can make informed decisions to enhance the health and productivity of their herds.

This study aims to delineate the patterns of SCC variation through the lactation cycle, providing insights into normal physiological changes versus indications of udder health issues, which can aid in developing more precise management strategies to enhance milk quality and animal welfare.

Materials and Methods

Study Design
This research was a longitudinal observational study conducted on a cohort of 100 cross-bred dairy cows over a period of one year from Kashmir India. The primary objective was to monitor and analyze the dynamics of somatic cell count (SCC) across various lactation stages.

1. Selection of Subjects: A total of 100 dairy cows were selected based on predefined criteria, including health status, breed, and stage of lactation. The cows were housed in a free-stall barn with access to a controlled diet and water ad libitum. The selection aimed to minimize external variability and focus on the natural progression of lactation phases.

2. Sampling Procedure: Milk samples were collected from each cow at four critical points corresponding to the lactation phases: within 24 hours post-calving (colostrum phase), 30 days (early lactation), 150 days (mid-lactation), and 210 days (late lactation). The sampling was conducted following strict hygienic protocols to prevent contamination and ensure the accuracy of SCC measurements.

3. SCC Measurement: Each sample was labelled, refrigerated at 4°C, and analyzed within 24 hours of collection for SCC using an electronic cell counter (DeLaval automatic SCC Counter, Tumba, Botkyrka, Sweden), recognized for its precision and reliability in dairy diagnostics. Each sample was analyzed in triplicate to account for any technical variability.

4. Data Collection and Management: Alongside SCC data, relevant information on each cow, including age, breed, parity, and health records, was meticulously documented. Environmental factors such as housing, feeding, and management practices were also recorded to identify any external influences on SCC levels.

Statistical Analysis
Data were analyzed using repeated measures ANOVA to assess the changes in SCC across different lactation stages. Post hoc comparisons were conducted using Tukey’s Honest Significant Difference test to identify statistically significant differences between phases. A p-value of less than 0.05 was considered statistically significant.

Results
The data collected in this study represents the somatic cell count (SCC) across different phases of lactation in crossbred cows (Table 1). The SCC is an important indicator of milk quality and udder health, with higher counts often associated with mastitis and other infections. The four phases of lactation considered are colostrum, early lactation, mid lactation, and late lactation. During the Colostrum Phase, the somatic cell count (SCC) ranged from a low of 544,701 to a high of 1,038,314, reflecting the expected elevated levels due to the presence of colostrum milk, which naturally contains higher immune cell counts. In the Early Lactation Phase, the SCC significantly decreased, with a highest observed value of 297,181 and a lowest of 96,500, indicating the transition from colostrum to regular milk. During the Mid Lactation Phase, the mean SCC rose to 380,678, with considerable variation from a minimum of 61,665 to a maximum of 724,485, likely due to environmental exposures and potential infections. Finally, in the Late Lactation Phase, SCC levels remained high, averaging 618,764, with a range between 322,740 and 824,089, possibly due to cumulative lactation stress and increased infection risk as lactation advanced (Table 2). The data demonstrates clear variation in SCC across the different lactation phases. The colostrum phase exhibits the highest mean SCC (820,974) and standard deviation (128,643), indicating significant variation and higher SCC levels immediately postpartum. Early lactation shows a notable decrease in SCC, with the lowest mean (190,858) and standard deviation (56,927), SCC levels increase again during mid and late lactation, with late lactation showing a mean SCC of 618,764.

Inference

Colostrum Phase: The SCC was highest immediately post-parturition, with an average count significantly higher than all other phases. This is likely due to the physiological changes and the immune system's activation in response to parturition (Fig 1).

Early Lactation: There was a marked decrease in SCC, indicating a stabilization of udder health as the cows recovered from calving.

Mid Lactation: SCC levels varied, showing no consistent pattern. This variability could be influenced by external factors such as environmental stress and variations in feed quality (Fig.2).
Fig 1: Shows the somatic cell count across different lactation phases

Late Lactation: An increase in SCC was observed, possibly due to the cumulative effects of lactational stress and the beginning of the involution process (Fig 3).

Fig 2: Shows the trends in somatic cell count during early, Mid and Late Lactation

Fig 3: This figure shows the distribution and density of SCC values across the different lactation phases. It combines the features of a box plot with a density plot, providing a detailed view of the data distribution.
Statistical Analysis
The ANOVA and regression analyses both reveal significant differences in Somatic Cell Count (SCC) across different lactation phases. The ANOVA results show an extremely high F-value (682.28) with a p-value close to zero, indicating that lactation phase significantly affects SCC. The regression analysis further supports this, with an R-squared of 83.8%, showing that the model explains a substantial proportion of the variance in SCC. The baseline SCC in the Colostrum phase is 8.02e+05, and the SCC significantly decreases in the Early, Mid, and Late Lactation phases by approximately 6.08e+05, 4.28e+05, and 1.88e+05 respectively. Both analyses confirm that SCC is significantly lower in these phases compared to the Colostrum phase, highlighting the strong influence of lactation phase on SCC levels in dairy cows.

Discussion
The dynamics of somatic cell count (SCC) across the lactation cycle, as observed in this study, provide critical insights into the physiological and health status of dairy cows. Each phase of lactation presents unique challenges and opportunities for managing udder health and milk quality. The notably high SCC observed immediately post-parturition is consistent with the body's natural response to the trauma of calving. This physiological reaction is partly due to the influx of immune cells into the mammary gland to repair tissue and combat potential pathogens. While high SCC during this phase is often physiological rather than pathological, it still necessitates careful monitoring to differentiate between normal elevations and those indicative of infections, such as mastitis.

The significant decrease in SCC during early lactation suggests a stabilization of the mammary gland's environment as it adapts to regular milking routines. This period is critical for establishing good milking practices and maintaining optimal cow health. Management strategies, such as ensuring proper milking machine function and teat sanitation, are crucial in minimizing the risk of infections that could cause elevations in SCC.

The variability observed in SCC during mid lactation this phase can be influenced by a myriad of factors, including nutritional status, environmental stressors, and overall animal health. This period may reflect the cow's response to external conditions, making it a critical point for intervention. Nutritional adjustments, stress management, and proactive veterinary care can help stabilize SCC levels, thereby enhancing milk quality and prolonging peak production. The increase in SCC towards the end of lactation is indicative of the physiological preparation for dry-off and may signal the onset of involution processes within the mammary gland. This increase can also be exacerbated by cumulative stress and potential neglect of late-lactating cows in favour of newly calving or peak-producing animals. It is essential to continue diligent udder health management throughout this phase to prevent the development of new infections or the exacerbation of existing ones, which can carry over into the next lactation cycle.

The findings of this study are in agreement with several previous studies that have explored the dynamics of somatic cell count (SCC) across different phases of lactation in dairy cows. The high SCC observed immediately post-parturition, reflecting the influx of immune cells to repair tissue and combat potential pathogens, aligns with findings by Nikodemusz et al. (1994) [8], who noted similar physiological responses in the early stages of lactation. The decrease in SCC during early lactation, indicative of the stabilization of the mammary gland environment, corroborates the results of Hagnestam-Nielsen et al. (2009) [5], who observed reduced SCC levels as cows adapted to regular milking routines (Hagnestam-Nielsen et al., 2009) [5]. The variability in SCC during mid-lactation, influenced by factors such as nutritional status and environmental stressors, is consistent with the findings of Breen et al. (2009) [1], who highlighted the impact of external conditions on SCC levels (Breen et al., 2009) [1]. Additionally, the increase in SCC towards the end of lactation, as the mammary gland prepares for dry-off, is supported by Green et al. (2009) [1], who documented similar trends and stressed the importance of ongoing udder health management. These findings collectively emphasize the critical need for phase-specific management strategies, as also suggested by Madouasse et al. (2010) [7], to enhance milk quality and animal welfare throughout the lactation cycle.

The findings from this study emphasize the need for phase-specific management strategies. For example, during thecolostrum and early lactation phases, intensive monitoring and gentle handling can reduce stress and enhance recovery. In mid-lactation, maintaining consistent and high-quality feed, alongside regular health check-ups, can mitigate the risk of SCC spikes. As cow approaches late lactation, continued attention to milking hygiene and cow comfort can help maintain udder health and milk quality.

Further research could explore the impact of specific interventions, such as dietary supplements or advanced milking technologies, on SCC dynamics. Additionally, investigating genetic factors that influence SCC responses could lead to more personalized management strategies. Understanding the relationship between cow behavior, environmental stressors, and SCC could also yield new insights into optimal dairy farm operations.

Overall, this study contributes to a more nuanced understanding of how lactation stages impact dairy cattle health and milk production, providing a foundation for improved management practices that can lead to better economic outcomes and animal welfare. Further studies are needed to delve into the underlying biological mechanisms governing SCC variations and explore innovative management and treatment strategies to enhance udder health and milk quality.
The study highlights the importance of understanding SCC trends across different lactation phases and the need for effective dairy management practices to maintain optimal udder health and milk quality. The physiological elevation of SCC during the colustrum phase is a natural response to parturition and does not typically indicate pathological mastitis. The stabilization of SCC in early lactation signals the normalization of udder health, whereas the lowest SCC levels in mid-lactation reflect the peak of mammary gland efficiency. The gradual increase in SCC during late lactation necessitates careful monitoring, as it may precede udder health challenges and affect subsequent lactation performance. Regular monitoring and timely intervention
can help mitigate the risks associated with high SCC levels, ensuring better health outcomes for the cows and higher quality milk production.

References