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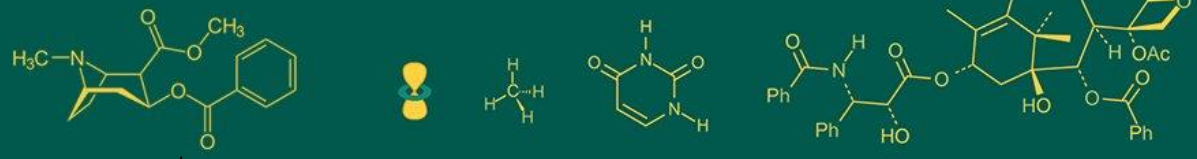

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Dynamics of somatic cell count in dairy cattle across lactation stages: Implications for udder health and milk quality

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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 (Green *et al*., 2004) [4]. This condition is a major cause of decreased milk production and quality in the dairy industry (Hagnestam-Nielsen *et al*., 2009) [5]. Understanding the natural variation of SCC across different lactation phases is crucial for distinguishing between physiological changes and pathological conditions (Schepers *et al.*, 1997) [9]. Research has shown that somatic cell counts are influenced by various factors including intra-mammary infections and the immune system's response in bovine animals (Vaidya *et al*., 2017) [10]. Lactation in dairy cows is divided into four main phases, each characterized by distinct physiological changes that can influence SCC levels (Hagnestam-Nielsen *et al*., 2009) [5]. During the colostrum phase, high SCC levels are common and considered normal due to the preparation of the mammary gland for milk production (Dohoo, 1993) [3]. As cows transition into early lactation, SCC levels typically decrease and stabilize, reflecting the establishment of regular milk production and udder health (Vliegher *et al*., 2005) [11]. Mid-lactation is often marked by the lowest SCC levels, although this can vary based on environmental factors and management practices (Schepers *et al*., 1997) [9]. Late lactation may see an increase in SCC due to physiological stress and the beginning of mammary gland involution in preparation for the next lactation cycle (Nikodemusz *et al*., 1994) [8]. The variation in somatic cell count (SCC) throughout the lactation cycle not only highlights the dynamic nature of mammary gland health but also emphasizes the complexity of managing dairy herd health. Elevated SCC levels, particularly during non-colostrum phases of lactation, can be indicative of subclinical or clinical mastitis, which necessitates timely intervention and management practices to mitigate the impact on milk production and quality.

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 colostral 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).

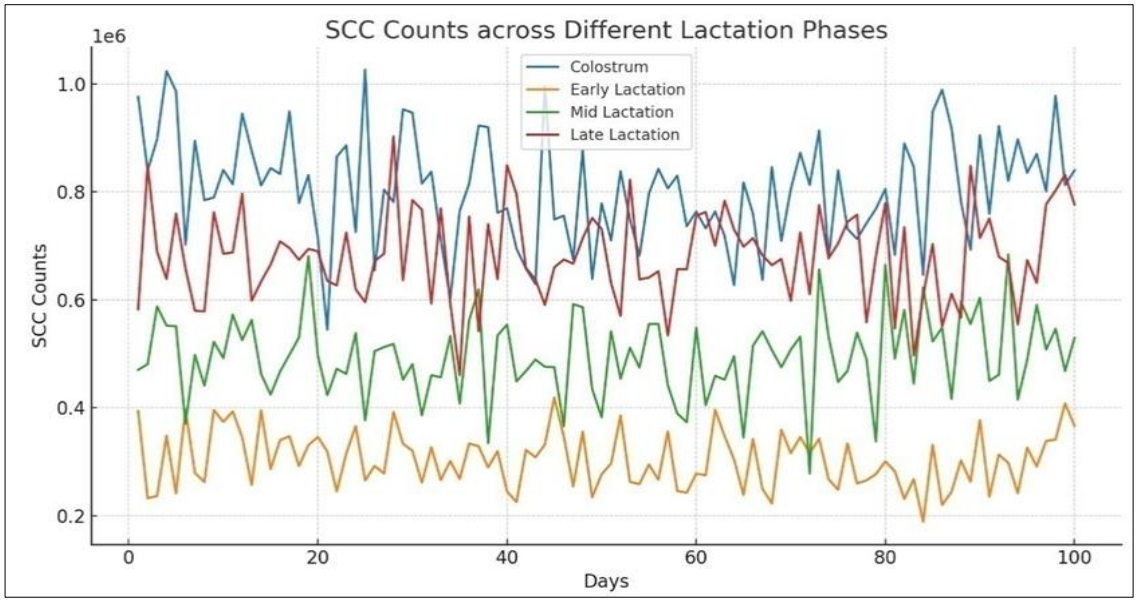

Fig 1: Shows the somatic cell count across different lactation phases

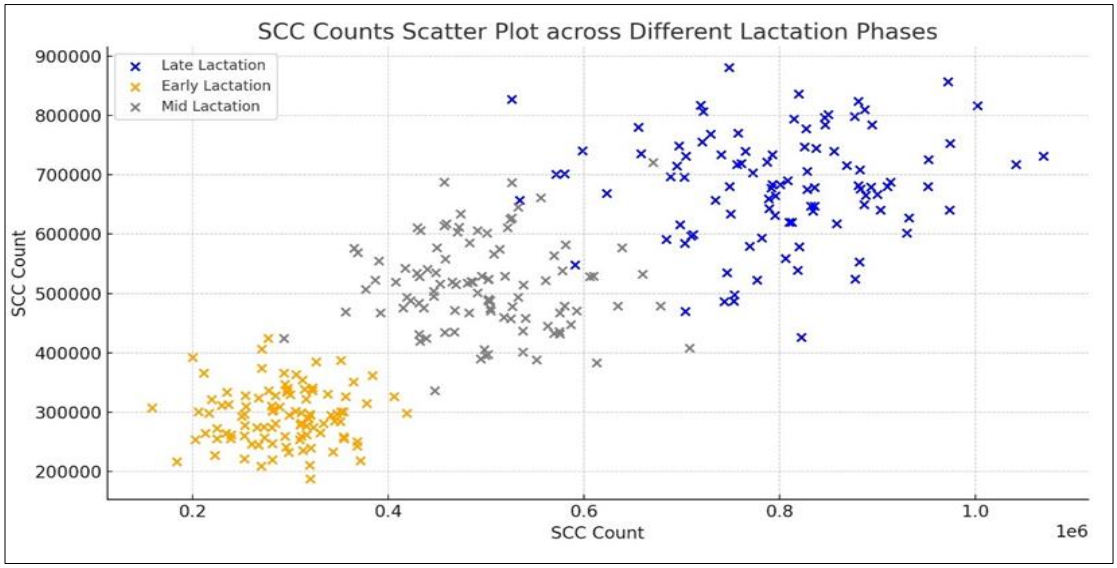

Fig 2: Shows the trends in somatic cell count during early, Mid and Late Lactation

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).

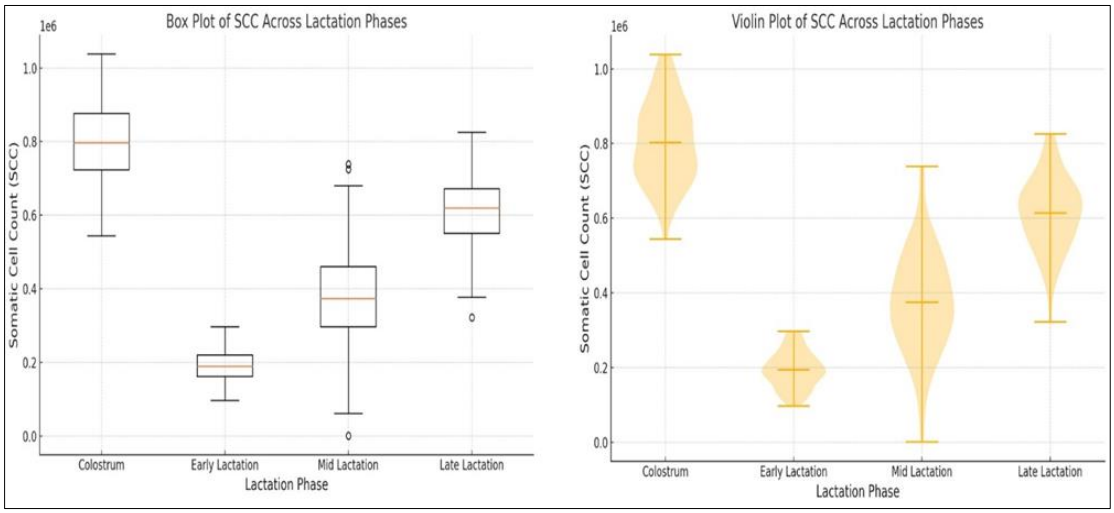

Fig 3: This figure shows the distribution and density of SCC values across the different lactation phases. It combines the features of a box plot with a density plot, providing a detailed view of the data distribution.

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 the colostrum 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.

Table 1: Somatic cell count during different phases of lactation in cross bred cows

S. no.	Colostrum	Early Lactation	Mid Lactation	Late Lactation	S. no.	Colostrum	Early Lactation	Mid Lactation	Late Lactation
1	976405	220007	546810	824089	51	763081	188031	564948	665526
2	986755	151136	542513	584864	52	864013	119152	396351	526196
3	789678	220529	421606	745427	53	827992	195092	536526	631721
4	876103	206083	466579	633367	54	878632	176679	258333	558995
5	949407	189742	446960	514590	55	798297	218957	738896	595774
6	544701	232680	529665	525783	56	704405	182700	330460	648148
7	1026975	127281	406863	581281	57	645920	203163	423475	623218
8	953277	273467	423242	637816	58	740268	188103	186390	550668
9	711221	100960	347813	615634	59	745713	220802	226572	678119
10	923029	260118	341900	569769	60	949448	96500	463938	667690
11	695144	128999	144059	795077	61	736256	180136	380067	570220
12	749034	178096	212080	677749	62	769098	116199	572849	707961
13	638610	189362	265680	638690	63	718663	126678	478159	542421
14	748919	140968	395772	642833	64	814195	184033	503730	669474
15	806651	215123	304851	563725	65	727440	130831	162559	661037
16	732753	182022	278028	427371	66	681114	174659	310552	594743
17	817742	179910	155470	646278	67	606372	209438	478583	608842
18	709270	202597	509363	612898	68	768911	204870	459856	322740
19	913940	138258	460351	531518	69	995591	219504	302138	560904
20	712920	171057	353267	605616	70	849374	194194	95397	806449
21	683485	245041	469849	446375	71	788945	251008	296192	753637
22	948825	294794	576816	582007	72	828634	230442	243211	721114
23	692924	252722	339523	722244	73	868981	265092	305786	551897
24	820827	248831	453454	670657	74	1030391	146999	379607	713689
25	801050	289293	419036	640198	75	809772	229147	340082	637005
26	988315	132612	209427	696939	76	669347	282906	382275	531982
27	682687	297181	337957	525254	77	866638	176964	199861	465328
28	992294	274025	680133	690604	78	869377	192021	379944	707774
29	713877	295503	359799	680245	79	687317	163466	342268	609435
30	894725	192249	492111	692220	80	795782	185655	390756	589269
31	837642	145029	444735	732638	81	728039	159350	441177	510908
32	730543	192518	334726	784926	82	684264	184385	376349	825672
33	867229	220373	284512	653924	83	729529	247163	512078	481105
34	732566	201591	304623	667643	84	877325	140805	1124	660631
35	857659	189585	459401	490693	85	624410	222546	297398	765955
36	650874	221969	425001	663503	86	906850	177330	296824	478592
37	1038314	247223	263076	711701	87	755907	185982	345295	615670
38	668409	176920	389763	771334	88	857852	217482	285378	456220
39	725524	158678	385232	533652	89	936453	165527	302155	547881
40	912663	146003	227879	556217	90	615693	176101	328051	662035
41	750196	296476	542413	608755	91	869845	200188	539777	633996
42	677456	242218	249967	445522	92	798431	208046	371401	560515
43	918802	215847	538128	631872	93	773226	143599	442066	500687
44	885683	167448	244863	668159	94	884163	187527	407424	649383
45	719659	165522	331670	601747	95	864331	121468	368964	688017
46	764600	131252	303457	377659	96	630189	219364	61665	497749
47	862523	119897	234342	605216	97	803863	117164	252173	452816
48	726043	277150	206071	626705	98	964813	208211	485093	577732
49	796071	141595	478491	582845	99	764656	119176	356224	523850
50	877179	241175	724485	733652	100	885792	257055	619986	685255

Table 2: Summary Statistics of Somatic cell count across the different lactation phases

Phase of Lactation	Mean SCC	Standard Deviation	Minimum SCC	Maximum SCC
Colostrum	820,974	128,643	544,701	1,038,314
Early Lactation	190,858	56,927	96,500	297,181
Mid Lactation	380,678	149,038	61665	724,485
Late Lactation	618,764	110,023	322,740	824,089

Conclusion

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 colostrum 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.

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