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(Original Article)

The Impact of Breed, Parity, and Calving Season on Somatic Cell Score in Dairy Cattle

Nisreen Othman*; Mohamed S. M. Mousa; Jalal A. Abd El-Hafez and Ahmed M.A. Hussein

Department of Animal Production, Faculty of Agriculture, Assiut University, 71515, Assiut, Egypt.

*Corresponding author: nisreen_othman@aun.edu.eg
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Abstract

The current study aimed to investigate the impact of breed, parity, and calving season on somatic cell score (SCS) in dairy cattle. Data was collected from 3,333 lactating cows, including 810 pure Holstein cows and 2,523 crossbred cows (Holstein pure with European breeds). Milk samples were taken monthly during morning milking sessions across four seasons within the period from 2002 to 2017. A General Linear Model (GLM) was applied to assess the effects of these factors on SCS. The results indicated that SCS was significantly higher ($P < 0.0001$) in cows with higher parity and was high in crossbreds compared to Holsteins ($P = 0.0460$). However, there was no significant effect of calving season on SCS. Additionally, weak negative phenotypic correlations were observed between SCS and milk (-0.09379), fat (-0.06733), and protein (-0.07158) yields. Based on these findings, dairy farmers and researchers can consider parity as a key factor to improve milk quality, udder health, and overall productivity in dairy cattle operations**.**

Keywords: *Breed, Calving season, Parity, Phenotypic correlation, Somatic cell score.*

Introduction

Milk, an inherently unique and essential white fluid, is the product of mammary gland secretion within bovine species. Notably, the inherent composition of raw milk plays a pivotal role in shaping the quality of dairy products, a matter of profound concern to milk processors who vigilantly monitor variations in its composition and physicochemical properties (Ivanov *et al.*, 2017) .

Composition, in this context, alludes to the composition of major milk constituents, such as protein, fat, lactose, total solids, and somatic cell count (SCC), the latter being a primary indicator of mammary gland health status *(*GUO *et al.,* 2010) and an essential metric for milk quality (Sert *et al.*, 2016). An increase in SCC levels in milk has been linked to alterations in various bovine milk components (Ramos Garcia *et al.*, 2015; de MACEDO *et al.*, 2018).

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High SCC in milk is often associated with intramammary infections, leading to a decrease in milk quality. This is due to alterations in the chemical composition of milk caused by the infection, leading to reduced levels of casein, lactose, and calcium, while increasing sodium, chloride, and serum proteins. (Pitkälä *et al.,* 2004). Previous studies have also noted correlations between decreased milk yield and elevated SCC (Bharti *et al.*, 2017).

The composition of milk is subject to various influences, including the season, lactation stage, feeding regimen, milking interval, breed, and age of dairy cattle (Heck *et al.*, 2009)**.** Somatic cell count (SCC) in milk, on the other hand, is influenced by mammary gland inflammation as well as several other factors such as age, parity, stage of lactation, season, breed, and environmental and management conditions (Marinov *et al.,* 2019). Deshapriya *et al.* (2019) have additionally observed that SCC in milk may vary based on factors like body condition score, lactation stage, cow's age, and breed.

The objective of the study was to analyse (1) the effect of some factors on somatic cell score, and (2) the relationships between somatic cell score and milk traits (milk yield, fat, and protein).

Materials and Methods

Animals and Location

This study was conducted using data from a population of 3,333 lactating cows housed at the University of Minnesota farm. The cohort included 810 pure Holstein cows and 2,523 crossbred cows, resulting from crosses between Holstein and various European breeds, including Jersey, Montbéliarde, Swedish Red, and Normande. Data collection took place over across four seasons within the period from 2002 to 2017.

Herd Management

During the housing period at the West Central Research and Outreach Center (WCROC), animal care and management adhered to the ethical guidelines set by the University of Minnesota's Institutional Animal Care and Use Committee (IACUC) under protocol number 1508-32966A.

Throughout the grazing season, which lasted from May to October, all cows were part of an organic grazing (ORG) dairy production herd. The ORG dairy cows had access to pasture for 20 hours per day, in accordance with the USDA National Organic Program's pasture rule, which requires organic dairy cows to graze for at least 120 days and obtain 30% of their daily dry matter intake (DMI) from pasture. The pastures featured a diverse botanical composition, including smooth bromegrass (*Bromus inermis* Leyss), orchard grass (*Dactylis glomerata*), meadow fescue (*Festuca pratensis*), alfalfa (*Medicago sativa*), red clover (*Trifolium pratense*), white clover (*Trifolium repens*), and kura clover (*Trifolium ambiguum* Bieb).

Stocking density was maintained at three cows per hectare, and the cows were rotated to fresh paddocks every two days based on forage availability, which was measured using an Electronic Filip's folding plate pasture meter (Jenquip, Feilding, New Zealand). In addition to pasture, each ORG cow received a daily supplement of 2.72 kg of organic ground corn and had unrestricted access to minerals via ground-level feeders in each paddock. Water was provided ad libitum, with troughs positioned at ground level within each paddock to ensure sufficient supply.

For the winter months, extending from November to April, ORG cows were transferred to an outwintering lot, where they were provided with a total mixed ration (TMR). This TMR primarily consisted of corn silage, alfalfa haylage, ground corn, soybean meal, and mineral supplements.

In contrast, during the summer months, the ORG herd relied predominantly on pasture forage, with minimal grain supplementation, resulting in 85% of their daily dry matter intake (DMI) coming from pasture. The quality of pasture forage varied throughout the study years, with an average composition of 18.0% crude protein (CP), 50.1% neutral detergent fiber (NDF), and 27.2% acid detergent fiber (ADF).

Milk Sample Collection

Milk samples were collected monthly during the morning milking session, which typically occurred between 7 a.m. and 12 p.m.

Measurement of Traits

Daily milk production for each cow was measured using the Boumatic Smart Dairy system (Madison, WI, USA). while monthly evaluations of fat percentage, protein percentage, and somatic cell score (SCS) were performed. The milk samples were analyzed at Stearns DHIA Laboratories (Sauk Centre, MN, USA), using a 4000/5000 Combi-Foss Milk Analyzer (Hilleroed, Denmark).

To monitor the health status of the cows, body weight was recorded bi-weekly with a digital scale. Additionally, after each milking session, body condition scores (BCS) were assessed by the same experienced individual, who had consistently recorded BCS in various research studies. BCS was graded on a scale from 1 (excessively thin) to 5 (excessively fat), ensuring consistent and reliable evaluations throughout the study.

Statistical analysis

All collected data were analyzed using the Statistical Analyses System (SAS, 2013, version 9.4, SAS Institute Inc., Cary, NC, USA). By PROC- GLM procedure (General Linear Model). The Duncan Multiple Range Test was used for comparison between the different traits (Duncan, 1995).

The following linear animal model was used for the production traits:

$$Y_{ijkl} = \mu + P_i + S_j + B_k + PS_{ij} + PB_{ik} + SB_{jk} + PSB_{ijk} + e_{ijkl},$$

Where:

Y_{ijkl}: individual observation of SCS, μ: Overall mean,

P_i: Fixed effect of the i^{th} parity (1 to 5),

S_j: Fixed effect of the j^{th} calving season (summer, spring, autumn and winter),

B_k: Fixed effect of the k^{th} breed (Holstein and Crossbred)

PS_{ij}: Interaction between i^{th} parity and j^{th} calving season,

PB_{ik}: Interaction between i^{th} parity and k^{th} breed,

SB_{jk}: Interaction between j^{th} calving season and k^{th} breed,

PSB_{ijk}: Interaction between i^{th} parity and j^{th} calving season and k^{th} breed and

E_{ijkl}: the residuals assumed independent error with zero mean and I sigma^2.

Results and Discussion

Effect of Breed on Somatic Cell Score (SCS)

The current study revealed that the impact of breed on somatic cell score (SCS) was statistically significant (P = 0.0460), which is more pronounced in Crossbred cows compared to Holstein cows. The mean ± SE of SCS in Holstein and Crossbred cows were 3.06 ± 0.04 and 3.22 ± 0.03, respectively, as shown in Table 1.

The findings of our study align with those of several researchers have reported that SCS is influenced by breed (Alhussien and Dang, 2018; Stocco *et al.*, 2023). Rupp and Boichard (2003**)** noted that breeds such as Montbéliarde, Abondance, Simmental, and Brown Swiss have fewer clinical mastitis cases than Holsteins, and their milk generally contains lower somatic cell counts. Genetic factors may explain the differences in somatic cell traits among these breeds. Despite genetic and phenotypic variations, innate immunity remains a core and evolutionarily conserved element of host defense mechanisms (Bannerman *et al.*, 2008).

This investigation also demonstrated a significant reduction in somatic cell count (SCC) within the high-yielding Holstein breed compared to the low-yielding Crossbred cows. Furthermore, correlation analysis (Table 6) revealed a negative correlation between milk production and SCC, supporting the observed SCC results.

Effect of Calving Season on Somatic Cell Score (SCS)

The results of the present study showed that the effect of calving season on SCS was higher in the spring season and lower in the summer season. The mean ± SE of SCS for spring, autumn, winter, and summer calving seasons were 3.22 ± 0.03, 3.14 ± 0.04, 3.14 ± 0.09, and 3.13 ± 0.10, respectively. However, the differences in SCS between the seasons were not statistically significant, as shown in Table 1.

These findings align with the research by *Coleman and Moss (1989),* who indicated that Holstein cows have the highest somatic cell count (SCC) in May and

June (412,000/ml) and the lowest in July and August (132,000/ml). However, they proposed that the season does not influence SCC in Holstein cows. In contrast, some authors have reported higher SCC in milk during the summer season (Erdem *et al.,* 2007; Najafi *et al.,* 2009). They attributed the higher summer SCC to stress from elevated temperatures and humidity, which increases exposure to pathogens and susceptibility to infections and mastitis (Ribas *et al.,* 2014; Simioni *et al.,* 2014).

Table 1. Effect of breed, calving season and parity on somatic cell score

Animal factors	No. of observations	SCS (Means±SE)	P
Breed			
Holstein	810	3.06^{B}±0.04	=0.0460
Crossbred	2523	3.22^{A}±0.03	
Calving season			
Autumn	1191	3.14^{A}±0.04	0.8489
Spring	1802	3.22^{A}±0.03	
Summer	130	3.13^{A}±0.10	
Winter	210	3.14^{A}±0.09	
Parity			
1	1318	3.09^{D}±0.03	<0.0001
2	902	2.91^{E}±0.04	
3	609	3.33^{C}±0.05	
4	340	3.63^{B}±0.07	
5	164	3.99^{A}±0.10	

Different letters (a, b, c, d, e) represent significant differences among traits.

Effect of Parity on Somatic Cell Score (SCS)

The present study indicated that parity had a significant effect (P < 0.0001) on SCS, with the lowest SCS observed in second parity and the highest in fifth parity. The mean ± SE of SCS for parities 1, 2, 3, 4, and 5 were 3.09 ± 0.03, 2.91 ± 0.04, 3.33 ± 0.05, 3.63 ± 0.07, and 3.99 ± 0.10, respectively, as depicted in Table 1. The differences among them were statistically significant.

Previous studies have reported that SCC increases with the number of parities (Sebastino *et al*., 2020; Atashi and Hostens, 2021), which is consistent with our findings. Additionally, De Haas (2003*)* reported that SCC rises with the number of lactations, suggesting this is due to varying protective mechanisms against udder infections in younger and older cows. As cows age, they lose body condition, and the udder tissues become more susceptible to invasion by microorganisms, leading to a higher incidence of mastitis.

Effect of interaction between breed & season on SCS

The interaction between breed and season was found to be not significant on SCS, as depicted in Table 2.

Table 2. Effect of interaction between breed & season on SCS

	Breed × Season			
	Autumn	**Spring**	**Summer**	**Winter**
Holstein	3.08±0.07	3.04±0.06	2.99±0.18	3.16±0.15
Crossbred	3.17±0.05	3.26±0.03	3.21±0.12	3.13±0.11

Pr = 0.5899

Effect of interaction between breed & parity on SCS

Table 3 illustrates that the interaction between breed and parity did not exert a statistically significant influence on somatic cell score.

Table 3. Effect of interaction between breed & parity on SCS

Breed × Parity					
	1	2	3	4	5
Holstein	2.83±0.06	2.82±0.08	3.29±0.10	3.61±0.14	4.08±0.22
Crossbred	3.17±0.04	2.93±0.05	3.35±0.06	3.64±0.08	3.96±0.12

Pr = 0.8943

Effect of interaction between season & parity on SCS

The interaction between season and parity was not significant on SCS, as shown in Table 4.

Table 4. Effect of interaction between season & parity on SCS

Season × Parity					
	1	2	3	4	5
Autumn	2.93±0.06	2.88±0.07	3.24±0.08	3.73±0.12	4.01±0.17
Spring	3.18±0.05	2.94±0.06	3.39±0.08	3.53±0.10	3.91±0.13
Summer	2.98±0.17	2.80±0.17	3.38±0.21	3.47±0.32	4.23±0.59
Winter	3.04±0.13	2.82±0.14	3.44±0.21	3.79±0.39	4.51±0.51

Pr = 0.7149

Effect of interaction between breed & season & parity on SCS

The interaction of breed, season, and parity was not significant on SCS, as depicted in Table 5

Table 5. Effect of interaction between breed & season & parity on SCS

Holstein			Crossbred		
Season	Parity	(Mean±SE)	Season	Parity	(Mean±SE)
Autumn	1	2.74±0.11	Autumn	1	2.99±0.07
	2	2.87±0.12		2	2.89±0.08
	3	3.16±0.14		3	3.27±0.10
	4	3.69±0.19		4	3.75±0.15
	5	4.24±0.37		5	3.91±0.19
Spring	1	2.86±0.09	Spring	1	3.27±0.05
	2	2.79±0.12		2	2.98±0.06
	3	3.40±0.17		3	3.39±0.08
	4	3.50±0.22		4	3.54±0.11
	5	3.91±0.25		5	3.92±0.16
Summer	1	2.99±0.26	Summer	1	2.97±0.23
	2	2.43±0.29		2	3.02±0.20
	3	3.46±0.38		3	3.35±0.26
	4	3.35±0.70		4	3.51±0.37
	5	5.48±0.0		5	3.92±0.65
Winter	1	2.91±0.24	Winter	1	3.09±0.16
	2	2.99±0.19		2	2.74±0.19
	3	3.45±0.37		3	3.44±0.25
	4	3.89±0.80		4	3.71±0.40
	5	3.25±0.03		5	5.13±0.52

Pr = 0.7071

Phenotypic Correlation Between Somatic Cell Score (SCS) and Milk Production Traits

Somatic cell score (SCS) exhibited a weak but highly significant negative correlation with milk yield, milk fat, and milk protein (P < 0.0001). The negative correlation between SCS and milk yield and composition has been well-documented by many researchers **(**Guo *et al*., 2010; Atashi *et al.,* 2021**)**. These negative correlations align with the detrimental impact of poor mammary health on production (Rajala-Schultz *et al*., 1999). Increased SCC levels were significantly associated with reductions in milk yield, as well as decreases in fat and protein yields **(**Guo *et al*., 2010).

However, several studies have shown a positive correlation between SCS and both milk yield and milk composition (Guo *et al.,* 2010; Cinar *et al.,* 2015; Pelmuș *et al*., 2022).

Table 6. Phenotypic correlation between somatic cell score and milk production traits

Parameters	305 milk	305 Fat	305 Protein
Pr	<0.0001	<0.0001	<0.0001
305 SCS	-0.09379	-0.06733	-0.07158

Conclusion

This study highlights the significant influence of various factors on somatic cell score (SCS) in dairy cattle. The findings suggest that breed, parity, and calving season play crucial roles in determining the quality and quantity of milk produced. By understanding and accounting for these factors, dairy farmers and researchers can make informed decisions to enhance milk quality, udder health, and overall productivity in dairy farming practices.

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تأثير السلالة وعدد الولادات وموسم الولادة على عدد الخلايا الجسدية في الابقار الحلابة

نسرين عثمان، محمد سليمان مصيلحي موسي، جلال عبد المطلب عبد الحافظ، أحمد محمد عبد الله حسين

قسم الإنتاج الحيواني، كلية الزراعة، جامعة أسيوط، أسيوط، مصر.

الملخص

تم إجراء الدراسة الحالية لمعرفة تأثير السلالة، عدد الولادات، وموسم الولادة على عدد الخلايا الجسدية في أبقار الألبان. تم جمع البيانات من 3333 بقرة حلابة، تتكون من 810 بقرة من سلالة الهولشتاين النقية ،2523 بقرة خليطة (هولشتاين نقيه مع سلالات أوروبية).

تم أخذ عينات الحليب شهريًا خلال جلسات الحلب الصباحية على مدار أربعة مواسم في الفترة من 2002 إلى 2017. تم استخدام نموذج خطي عام (GLM) لتقييم تأثير هذه العوامل على عدد الخلايا الجسدية (SCS) أشارت النتائج إلى ان عدد الخلايا الجسدية كانت أعلى بشكل ملحوظ ($P < 0.0001$) في الأبقار ذات عدد الولادات الأعلى وأعلي في الابقار الخليطة مقارنه بأبقار الهولشتاين ($P = 0.0460$). ومع ذلك، لم يكن هناك تأثير لموسم الولادة على عدد الخلايا الجسدية. بالإضافة إلى ذلك، لوحظت ارتباطات مظهريه ضعيفة وسلبية بين عدد الخلايا الجسدية وإنتاج الحليب (0.09379-) وإنتاج الدهن (0.06733-) وإنتاج البروتين (0.07158-). بناءً على هذه النتائج، نقترح أنه تحت ظروف هذه الدراسة، يمكن لمزارعي الألبان والباحثين اتخاذ قرارات مستنيرة لتحسين جودة الحليب وصحة الضرع والإنتاجية العامة في ممارسات تربية الأبقار الحلوب بعد أخذ هذه العوامل بعين الاعتبار.

الكلمات المفتاحية: *الارتباط المظهري، السلالة، عدد الخلايا الجسدية، عدد الولادات، موسم الولادة.*