Black Sea Journal of Engineering and Science
doi: 10.34248/bsengineering.1857045

Open Access Journal
e-ISSN: 2619 – 8991

Research Article
Volume 9 - Issue 2: 624-632 / March 2026

DIFFERENCES IN BREEDING SYSTEMS CAN AFFECT THE BODY HYGIENE STATUS AND PRODUCTIVITY OF ANATOLIAN BUFFALO COWS

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Abstract: This study aimed to evaluate the effect of different breeding systems [intensive systems (IS) and semi-intensive systems (SIS)] on the body hygiene status of Anatolian buffalo cows (udder, upper and lower rear limbs, and tail), as well as on milk yield per milking (MYM), dry matter (DM), fat, non-fat solids (SNF), protein, the fat-to-protein ratio (FPR), lactose, density, freezing point (FP), somatic cell count (SCC), pH and electrical conductivity (EC). Additionally, the relationships between the variables examined with body hygiene scores [udder hygiene score (UHS), upper rear limbs hygiene score (URS) and lower rear limbs hygiene score (LRS), and tail hygiene score (THS)] were evaluated. A total of 160 primiparous cows were selected from sixteen commercial farms in Samsun, Türkiye. The farms were grouped according to their breeding system: IS (n = 80) and SIS (n = 80), with eight farms in each group utilising semi-open free-stall housing. The milk's MYM was determined using a digital scale, while an automated milk analyser was used to analyse the milk samples and determine their components, such as DM, fat, SNF, protein, lactose, minerals, density and FP. The SCC, pH and EC values were determined using a somatic cell counter, pH meter and EC meter, respectively. Differences between the IS and SIS groups were evaluated using t-tests for milk quality traits and Mann–Whitney U tests for hygiene scores. Spearman's correlation was used to determine the relationship between anatomical hygiene scores and milk quality parameters. The results showed that SIS management resulted in significantly higher hygiene scores in all anatomical regions of cows than IS management did. The SCC and EC were higher in the SIS cows than in the IS group, but their milk had a lower protein content and density. As body parts hygiene score increased, the cows' SCC, EC and pH increased, but their MYM and some milk components. This study concluded that SIS cows had poorer body hygiene than IS cows in all examined body regions, which could negatively affect SCC and EC—accepted indicators of udder health and milk hygiene—and ultimately milk protein content and milk density.

Keywords: Anatolian buffaloes, Farming conditions, Body hygiene, Milk quality, Milk yield per milking

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Received: January 05, 2026
Accepted: February 06, 2026
Published: March 15, 2026

Cite as: Okuyucu, İ. C. (2026). Differences in breeding systems can affect the body hygiene status and productivity of Anatolian buffalo cows. *Black Sea Journal of Engineering and Science*, *9*(2), 624-632.

1. Introduction

Water buffaloes (*Bubalus bubalis*) are generally kept in enclosed barns or semi-open free barns worldwide, either for part of the year or throughout the year (Okuyucu et al., 2024). This species commonly grazes on natural pastures during certain periods of the year (Degirmencioğlu et al., 2015; Atasever, 2022). In other words, water buffaloes (hereafter buffalo) are mostly raised in semi-intensive production systems that offer pasture-based farming conditions. However, the unique milk quality traits of buffaloes have increased interest in their products, accelerating the adoption of intensive farming conditions. Therefore, the intensification of buffalo cows breeding conditions has led many researchers to focus on improving animal welfare, health and productivity parameters such as milk yield and quality traits (Akdağ et al., 2024; Okuyucu et al., 2024).

Buffaloes have a different morphological and physiological structure that can create a series of disadvantages in hot climates. Compared to cattle, buffaloes have darker skin colour, sparser hair, and fewer sweat glands, causing them to struggle to regulate their body temperature, especially in hot climates. Therefore, especially during seasons when temperatures rise, those raised under semi-intensive conditions may need access to wetlands such as lakes, ponds, and rivers to regulate their body heat, while those raised under intensive conditions may require climate control measures such as artificial showers, sprinklers, and fogging systems (Yáñez-Pizaña et al., 2020). Understanding the comfort and social and/or environmental needs of buffaloes is a key determinant of improving their health, well-being, and milk quality traits (Mincu et al., 2022). Differences in the raising conditions and accessibility of pastures for buffalo cows are the main sources of contamination due to mud, moisture, and manure (DeVries et al., 2012; Saber et al., 2017). A large body of researcher have reported that sources of microorganisms such as mud

and manure in animal bodies can negatively affect both udder health and the quality and quantity of milk parameters of the cow (Schreiner and Ruegg 2003; Reneau et al., 2005; Erdem and Okuyucu, 2019; Robles et al., 2020). Indeed, these researchers have reported that poor body hygiene in dairy cows (cattle) increases somatic cell count (SCC), which is considered an indicator of milk hygiene (Schreiner and Ruegg, 2003; Reneau et al., 2005), and may therefore negatively affect udder health and milk quality characteristics [dry matter (DM), protein, and minerals; Erdem and Okuyucu, 2019]. In contrast, a study conducted on buffaloes reported that cooling behaviors in water or mud under pasture conditions, or high levels of contamination in barn environments, did not negatively impact the udder infection of the buffaloes (Bulu, 2019). A review of the literature reveals that studies on the relationship between body hygiene status and udder health and milk quality traits have generally focused on dairy cattle (Schreiner and Ruegg, 2003; Reneau et al., 2005; Erdem and Okuyucu, 2019). However, studies examining the relationship between body hygiene and milk quality traits in buffaloes, which are considered to be more resistant to the effects of udder infections than cattle, are limited (Saber et al., 2017; Bulu, 2019). Additionally, during warm seasons, the effects of access to wetlands—where these animals can exhibit climate adaptation behaviors due to their morphological and physiological characteristics—on their body hygiene and udder health remain controversial. Therefore, it is necessary to investigate how the body hygiene status of buffaloes raised in production systems where access to pasture is provided and in production systems where they are continuously confined in shelters changes, and how this affects udder health, milk hygiene, and milk quality traits. It is hypothesised that divergent rearing environments—specifically intensive versus semi-intensive production systems—exert a significant influence on the body hygiene status of dairy cows, this effect subsequently changed udder health indicators, milk yield, and milk quality attributes. The objective of this study was to evaluate the influence of different breeding systems (BS) [intensive systems (IS) vs. semi-intensive systems (SIS)] on the body hygiene status of cows (udder, upper rear limb, lower rear limb and tail), milk yield per milking (MYM), DM, fat, fat, non-fat solid (SNF), protein, fat-to-protein ratio (FPR), lactose, density, freezing point (FP), somatic cell count (SCC), pH, electrical conductivity (EC).

2. Material and Method

This observational study involved 160 primiparous Anatolian buffaloes across 16 commercial farms in Samsun, Türkiye. The observations and sample collection were performed twice at 14-day intervals on cows with days in milk (DIM) ranging from 38 to 57. The cows were categorized based on their management systems into IS (n = 8 farms) and SIS (n= 8 farms) groups. Ten healthy primiparous cows were selected from each farm. The IS and SIS cows were raised in semi-open free-stall barns, where they were fed a total mixed ration (TMR) twice daily and milked once a day. Similar feeding conditions were applied on all farms. The milking and feeding practices of IS cows carried out in barns and they were not allowed access to pasture. The IS cows were fed TMR twice a day: morning and evening. Following morning milking, the SIS cows was provided with a TMR in the barn for approximately one hour prior to accessing the pasture. These animals were maintained on a consistent diurnal grazing schedule from 09:00 to 17:00 each day. After grazing, the SIS cows was offered the same TMR as in the morning session, to ensure nutritional consistency. IS cows were not subjected to air conditioning processes such as artificial showers, fountains, fogging and artificial ponds. However, SIS cows grazed on pastures with wetlands such as ponds and marshes, which provided them with the conditions necessary to roll and cool themselves.

Routine milking procedures were not interfered with at all farms, and the milking processes were similar. All cows were milked between 05:00 and 07:00 using a portable milking machine (PLS-2/1, Sezer, Bursa, Türkiye). To ensure good milking hygiene, the cows' udders were washed with warm water before milking and dried with a clean cloth. To facilitate milk flow and provide necessary pre-stimulation, all cows nursed their calves for one minute. Then, two milking cups were attached to the front teats, but the two rear teats were reserved for calf feeding. During milking, calves were kept close to the cows, and the milking process was performed individually for each cow. To determine the MYM of each cow, the milk collected in a bucket was weighed on an electronic scale and recorded in kg. In addition, a homogeneous 50 ml sample was taken from each collected milk.

To determine milk quality traits for the present study, milk was transported to the laboratory in a cold chain bag maintained at +4°C for approximately 1 hour. All milk samples were heated in a water bath to 35°. Milk DM, fat, SNF, protein, lactose, and mineral percentages, as well as milk density (mg/mL) and FP (°C), were analyzed using an automated milk analyzer (Lactostar, Funke-Gerber, Germany). The FPR was calculated by determining the percentage of fat to protein. Milk EC (mS/cm) conductivity was measured using an EC meter (FiveEasy Plus, Mettler Toledo, Switzerland) equipped with a conductivity sensor. The pH was also measured using a calibrated pH meter (Testo 205 pH meter, Lenzkirch, Germany). SCC per milliliters was analyzed using a commercially available DeLaval Cell Counter (DCC; DeLaval International AB, Tumba, Sweden) as described by Sahin et al. (2014).

Udder hygiene score (UHS), upper rear limb hygiene score (URS), lower rear limb hygiene score (LRS) and tail hygiene score (THS) of the cows were determined by a single observer, using international scoring charts adapted by Reneau et al. (2005) for 4 anatomical regions.

As previously described by Okuyucu et al. (2024), body hygiene score was assessed subjectively on a five-point scale for each body region: 1 = very clean; 2 = clean; 3 = dirty; 4 = very dirty; 5 = manure encrusted. The body hygiene of all the cows was assessed, and milk samples were collected twice at seven-day intervals.

All data were analyzed using SPSS (version 21.0, SPSS Inc., Chicago, IL, USA). Normality and homogeneity of variance in data relating to body hygiene and production (milk yield and quality) traits were tested using the Kolmogorov-Smirnov and Levene tests, respectively ($p > 0.05$). The body hygiene scores and milk yield and quality traits of the IS and SIS groups were compared using Mann–Whitney U tests and t-tests, respectively. Additionally, t-tests were employed to analyse the differences in milk yield and quality characteristics in relation to the examined factors. A logarithmic transformation was applied to the SCC data because it did not satisfy the assumption of a normal distribution. Spearman's correlation analysis was used to evaluate the relationships among hygiene scores for four anatomical regions, as well as the relationships between these scores and quantitative-qualitative milk parameters.

3. Results

Table 1 show that different breeding systems (BS) affect UHS and URS, LRS and THS in primiparous Anatolian buffalo cows. The SIS cows were higher than the UHS ($P=0.001$), URS ($P<0.001$), LRS ($P<0.001$) and THS ($P<0.001$) IS cows.

BS did not affect the MYM of the cows, as well as milk DM, fat, SNF, FPR, lactose, minerals, FP, and pH (Table 2). However, the milk protein content of SIS cows was lower than that of IS cows ($P=0.030$), but their EC and SCC were higher ($P<0.001$).

Significant correlations of varying strength were observed among the body hygiene score (UHS, LRS, URS and THS; Figure 1). THS was positively correlated with LRS ($r = 0.797$), URS ($r = 0.741$), and UHS ($r = 0.758$). Furthermore, LRS was positively correlated with URS ($r= 0.797$) and UHS ($r = 0.883$). Similarly, URS was positively correlated with UHS ($r= 0.780$)

Figure 2, 3 shows the correlation coefficients between hygiene score of different anatomical regions and MYM and milk quality traits. UHS was positively correlated with SCC, pH, EC, FP and mineral but correlated negatively with density, lactose, protein, SNF, fat, DM, and MYM (Figure 2a). Similarly, URS was positively correlated with SCC, pH and EC, but correlated negatively with density, lactose, protein, SNF, fat, DM and MYM (Figure 2b).

Similar correlations were calculated for both the LRS and the THS (Figure 3a, b). As LRS increased, the cows' SCC, EC, pH and mineral increased, but their MYM, DM, fat, SNF, protein, lactose content, and density decreased. Furthermore, THS increased the cows' SCC, EC and pH increased, but their MYM, DM, fat, SNF, protein, lactose content, and density decreased.

Table 1. Mean body hygiene scores for the IS and SIS management

Body hygiene score	BS	n	Mean	Median (min-max)	SEM	Z	P-value
UHS	IS	160	1.61[a]	1 (1-3)	0.444	-3.444	0.001
	SIS	160	1.94[b]	2 (1-3)			
URS	IS	160	1.51[e]	1 (1-3)	0.428	-4.340	< 0.001
	SIS	160	1.89[d]	1 (1-3)			
LRS	IS	160	1.65[k]	2 (1-3)	0.438	-4.124	< 0.001
	SIS	160	2.03[l]	2 (1-3)			
THS	IS	160	1.54[y]	1 (1-3)	0.430	-5.051	< 0.001
	SIS	160	1.96[z]	2 (1-3)			

UHS, udder hygiene score; URS, upper rear limb hygiene score; LRS, lower rear limb hygiene score, THS, tail hygiene score; BS, breeding system; IS, intensive system; SIS, semi-intensive system; SEM, standard error of the mean

[a-b]Mean values in the same column with different superscripts differ ($P<0.05$) for UHS.

[e-d] Mean values in the same column with different superscripts differ ($P<0.05$) for URS.

[k-l]Mean values in the same column with different superscripts differ ($P<0.05$) for LRS.

[y-z]Mean values in the same column with different superscripts differ ($P<0.05$) for THS.

Table 2. Mean quantitative and qualitative milk parameters for IS and SIS management

Variables	IS	SIS	SEM	P-Value
Milk yield Trait				
MYM	3.43	3.34	0.027	0.101
Milk component (%)				
DM	17.77	17.57	0.124	0.424
Fat	7.74	7.72	0.069	0.885
SNF	10.03	9.85	0.079	0.258
Protein	4.42	4.24	0.041	0.030
FPR	1.79	1.87	0.021	0.056
Lactose	4.80	4.73	0.038	0.411
Mineral	0.64	0.63	0.004	0.369
Milk physical trait				
Density (mg/ml)	1.03	1,02	0.001	0.006
FP (°C)	-0.57	-0.55	0.007	0.679
EC (mS/cm)	3.52	3.71	0.265	< 0.001
pH	6.53	6.56	0.108	0.148
SCC (x 10^3 cell/ml)	87.8	127.9	5.25	< 0.001

IS= intensive system, SIS= semi-intensive system, SEM= standard error of the mean, MYM= milk yield per milking, DM= dry matter, SNF= non-fat solids, FPR= the fat-to-protein ratio, FP= freezing point, SCC= somatic cell count, EC= electrical conductivity

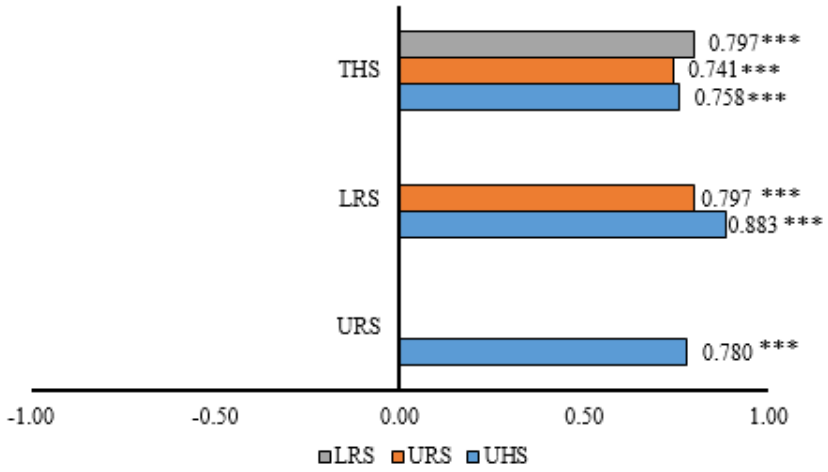

Figure 1. Correlation coefficients among body hygiene score in primiparous Anatolian buffalo cows subjected to IS or SIS, calculated by Spearman correlation analyses (***P<0.001), UHS= udder hygiene score, URS= upper rear limb hygiene score, LRS= lower rear limb hygiene score, THS= tail hygiene score.

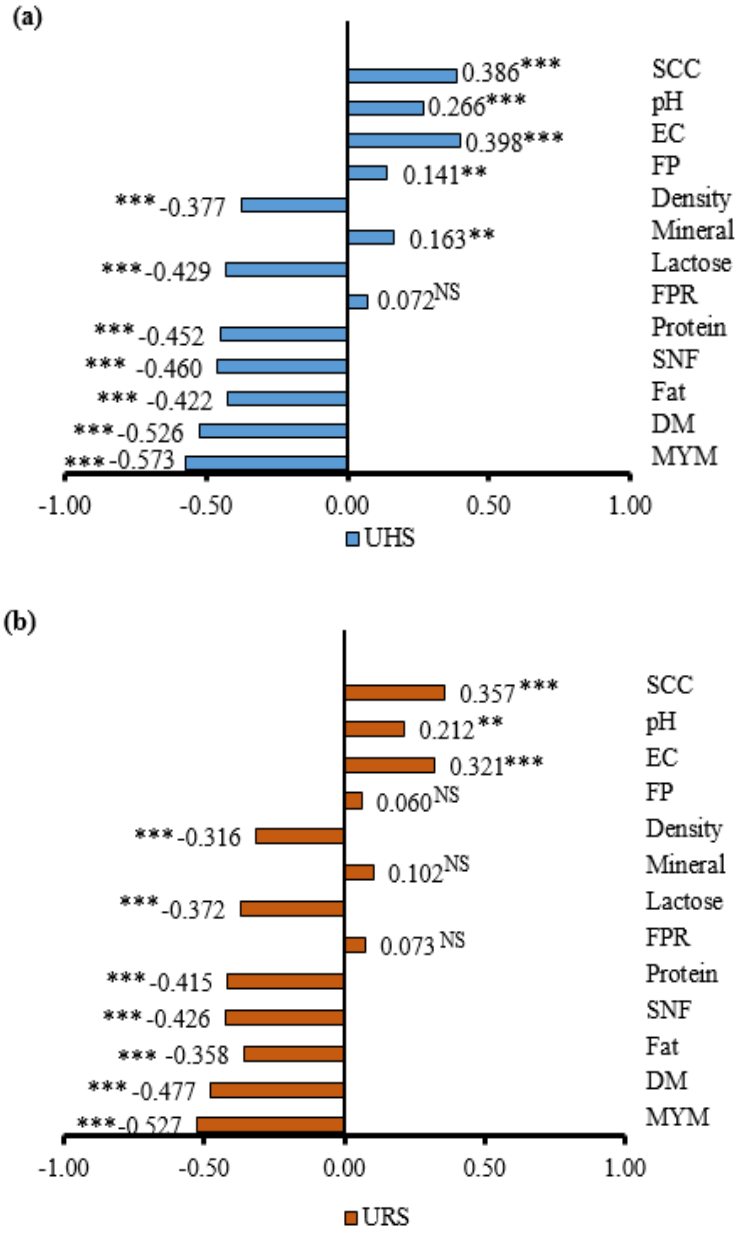

Figure 2. Correlation coefficients between body hygiene score (UHS and URS) and MYM and milk components in primiparous Anatolian buffalo cows subjected to IS or SIS, calculated by Spearman correlation analyses (**P<0.01; *** P<0.001; NS: not significant); UHS= udder hygiene score, URS= upper rear limb hygiene score.

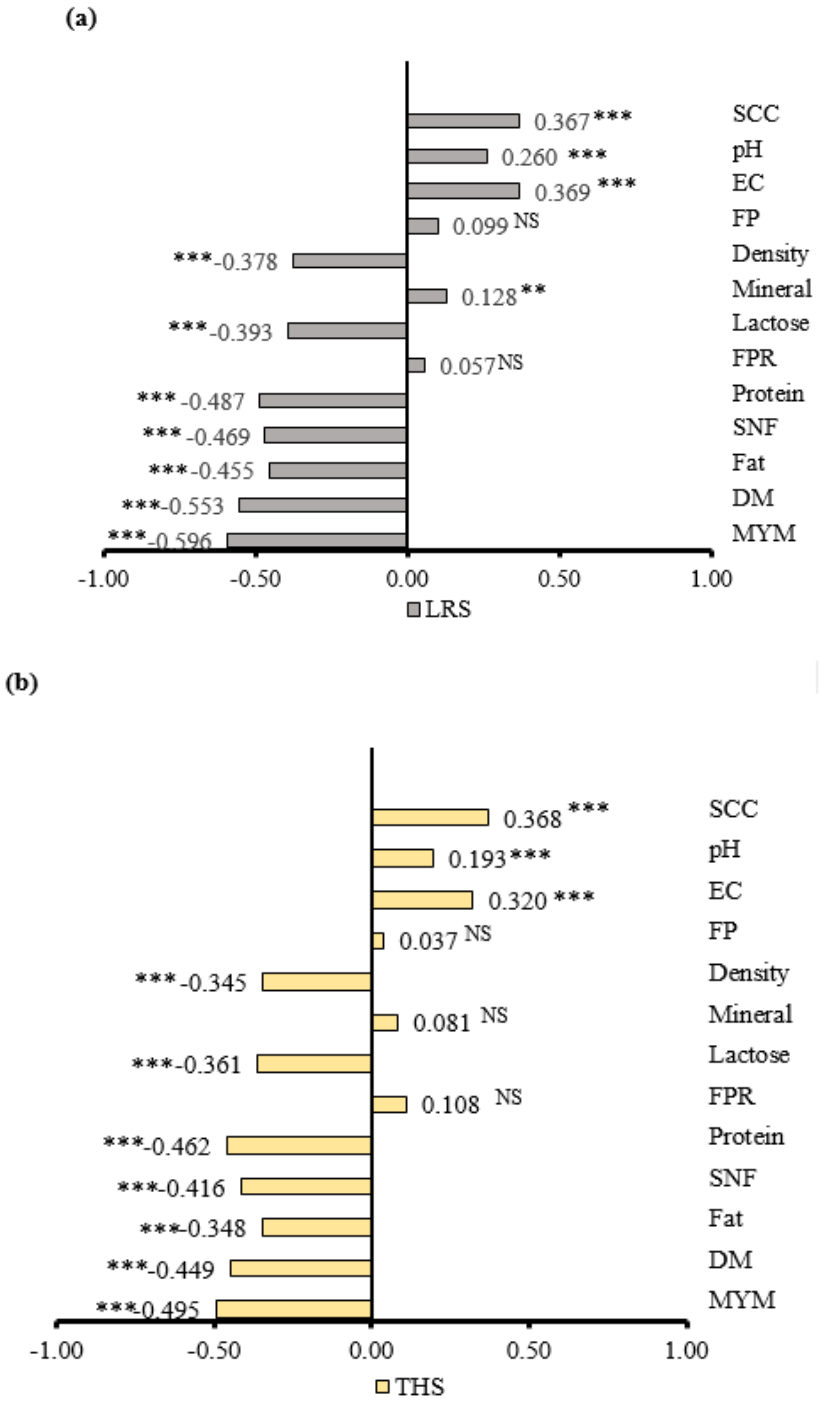

Figure 3. Correlation coefficients between body hygiene score (LRS and THS) and MYM and milk components in primiparous Anatolian buffalo cows subjected to IS or SIS, calculated by Spearman correlation analyses (**P<0.01; ***P<0.001; NS: not significant), LRS= lower rear limb hygiene score, THS= tail hygiene score.

4. Discussion

These results may contribute to a better understanding of how body hygiene scores (UHS, URS, LRS, and THS values), considered indicators of the hygiene status of different anatomical regions of cows (Reneau et al., 2005), are affected by IS and SIS, and their relationships with milk parameters. These results reveal that different rearing systems (IS vs. SIS) have a significant effect on the quantitative and qualitative milk parameters, as well as the body hygiene scores of buffalo cows. Furthermore, the correlation between the body hygiene scores affected by the factors studied and the variables examined is also significant.

A notable finding of the present study was that IS cows had lower UHS, LRS, URS, THS, EC and SCC, as well as higher milk protein and density, than SIS cows. The high hygiene score of all body regions in SIS cows can be explained by the fact that buffalo exhibit wallowing and cooling behaviours in response to morphological and physiological needs during the hot season (Napolitano et al., 2013; Napolitano et al., 2023). In other words, the presence of natural lakes and wetlands in the area where

SIS cows were grazed in this study resulted in very high levels of mud-related contamination, which may have increased the risk of contamination for the SIS cows. Although the design of this study did not allow for the observation of rolling and cooling behaviors, exhibiting these behaviors could increase the risk of contamination in wetlands and deteriorate their body hygiene. In addition, differences in the temperament of buffaloes can also affect their body hygiene. A study conducted on buffaloes reported that aggressive cows had increased UHS (Okuyucu et al., 2024). These results partially confirm that differences in herd management, breeding systems (Okuyucu et al., 2024), and individual animal behaviors can alter the welfare, comfort, and body hygiene status of cows (Aytekin et al., 2021; Çelebi and Akdağ, 2022). Each of these elements related to breeding and management has the potential to influence the body hygiene of cows, as well as their milk components and SCC. Therefore, industrial and scientific research should focus on developing breeding systems and management strategies that align with the physiological needs of this species.

Compared to IS cows, the higher UHS, URS, LRS, and THS in SIS cows indirectly increased SCC and EC values, and decreased milk protein content and density. Furthermore, the results of the present study confirm the positive correlations between body hygiene (UHS, LRS, URS and THS) and SCC and EC, and the negative correlations with milk components. These results are consistent with those obtained in studies conducted on cattle (Sant'Anna and Paranhos da Costa, 2011; DeVries et al., 2012; Erdem and Okuyucu, 2019; Aytekin et al., 2021) and buffaloes (Okuyucu et al., 2024). In contrast to the aforementioned findings, a separate study reported that elevated hygiene scores in buffalo cows across various body regions, such as UHS, URS and LRS were not associated with an increase in milk SCC (Bulu, 2019) EC (Saber et al., 2017). This discrepancy was explained by the hypothesis that buffalo cows possess superior immunological resistance to mammary gland pathogens compared to cattle (Bulu, 2019). Although buffaloes are characterized as resistant to mammary gland infections, the present study confirmed that poor body hygiene can increase SCC and EC values, which are considered indicators of udder health and milk hygiene. In this study, SCC was found to be 87.8 x 10^3 cell/ml for cows under IS management and 127.9 x 10^3 cell/ml for those under SIS management. The results of the current study were consistent with the findings of previous studies (from 9 x 10^4 to 13 x 10^5, Aydın et al., 2022; from 91.31 x 10^3 to 94.18 x 10^3, Kittur et al., 2024). Indeed, these studies reported that buffalo cows had a low SCC. Although these results may not directly negatively affect udder health in cows, they could increase the risk of subclinical mastitis (Aytekin and Boztepe, 2014). Furthermore, the inverse associations observed between hygiene scores (UHS, URS and LRS) and milk components (DM, SNF and protein) align with the findings reported by Bulu (2019), suggesting that increased body contamination is consistently linked to a decline in milk quality traits. However, these results cannot be attributed solely to poor body hygiene. Compared to IS cows, SIS cows have lower milk density and protein content, which may be due to SIS cows being fed fresh green grass in pastures. Although IS and SIS cows are fed TMR with similar DM ratios in the present study, the milk nutrient content of cows fed fresh green grass in pastures may be reduced. Indeed, many authors have reported that there may be differences in milk components between cows raised under pasture-based rearing conditions and those confined to barns (Boerman et al., 2015; Bulu 2019). Similarly, another study reported that in grazing-based systems, feed intake, animal behavior, and performance can be negatively affected by various factors, resulting in decreased productivity and reduced milk yield (Chiariotti et al., 2025).

These findings suggest that keeping cows in continuously barns (IS) creates a controlled environment, minimising their exposure to external pollutants and mud-derived residues and maintaining animal hygiene. When well-managed, IS systems can contribute to cleaner body hygiene and a reduced risk of environmental mastitis by facilitating frequent manure cleaning and controlled bedding. In contrast, although SIS systems improve animal welfare by facilitating natural social interactions and mud-rolling behaviours (Chiariotti et al., 2025), these activities can compromise external body hygiene. Poor body hygiene increases the risk of milk contamination and can negatively affect certain milk quality parameters. To determine the optimal management strategy, both BS must undergo rigorous analysis through the lens of multidimensional welfare criteria. In addition to productivity, integrating welfare metrics — specifically lameness, body condition and social behaviours — is essential for a robust comparative analysis.

5. Conclusion

The results of this study show that SIS cows have poorer body hygiene in all body regions examined compared to IS cows, which can negatively affect SCC and EC, considered indicators of udder health and milk hygiene, and ultimately milk protein content and milk density. Therefore, this study highlights welfare issues (body hygiene status) associated with differences in rearing conditions and reveals their relationships with quantitative-qualitative milk parameters under current conditions. IS provides a controlled social environment, minimizing cows' exposure to external pollutants and mud-derived residues, and improving udder health indicators as well as some milk quality characteristics. However, it should be noted that in IS, cows are provided with shower, sprinkler, and misting climate control options during hot seasons, and poor manure and bedding management can negatively impact body hygiene. Therefore, further studies are needed examining structural and managerial components such as barn type,

barn floor, bedding, and manure cleaning frequency to improve body hygiene, which is an animal-based welfare assessment criterion in IS cows.

Author Contributions

The percentages of the author' contributions are presented below. The author reviewed and approved the final version of the manuscript.

	İ.C.O
C	100
D	100
S	100
DCP	100
DAI	100
L	100
W	100
CR	100
SR	100
PM	100
FA	100

C= concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The author declared that there is no conflict of interest.

Ethical Consideration

The experimental procedures were approved by the Animal Ethics Committee of Ondokuz Mayis University in Samsun, Türkiye (Approval date December 25, 2025, protocol code: 2025/91).

Acknowledgements

The author wish to thank Republic of Türkiye Ministry of Agriculture and Forestry General Directorate of Agricultural Research and Policies and Samsun Provincial Buffalo Breeders association for support and contributions to the conduct of the experiment.

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