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EVALUATION OF BODY CONDITION, RUMEN FILL AND QUANTITATIVE-QUALITATIVE MILK PARAMETERS IN PRIMIPAROUS ANATOLIAN BUFFALO COWS HOUSED WITH OR WITHOUT ACCESS TO PASTURE

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Abstract: Water buffaloes (*Bubalus bubalis*) are typically raised in pasture-based production systems. However, production systems where buffaloes are confined permanently in barns (no grazing) or have access to pasture (pasture-grazing) have become more common recently. Therefore, differences in the production systems provided to buffalo cows may alter the welfare parameters and productivity of cow. This study aimed to investigate the effects of pasture-grazing (PG) and no grazing (NG) management practices on certain welfare assessment criteria [(body condition score (BCS) and rumen fill score (RFS)] and quantitative-qualitative milk parameters in primiparous Anatolian buffalo cows. This study was conducted on a total of 72 buffalo cows in two barns on a farm in Samsun, Türkiye: the first barn was pasture-grazing (PG, n=36) and the second barn was non-pasture-grazing (NG, n=36). Body condition and rumen fill were scored on a scale ranging from 1 to 5 to subjectively assess the nutritional status of cows. Additionally, milk samples were collected to determine quantitative-qualitative milk parameters [test-day milk yield (TDMY), dry matter (DM), fat, solids non-fat (SNF), protein, fat-to-protein ratio (FPR), lactose, density, freezing point (FP), somatic cell count (SCC), pH, electrical conductivity (EC)]. The milk components were analysed using an automatic milk analyser. Milk EC and pH were measured using a calibrated EC meter and pH meter, respectively. The SCC was determined using a somatic cell counter device. All statistical analyses were performed using SPSS. The BCS, RFS and quantitative-qualitative milk parameters of the PG and NG groups were compared using the Mann–Whitney U test and *t-test*, respectively. BCS and RFS of NG cows were higher than those of PG cows. Additionally, TDMY and milk protein content of NG cows were higher than those of PG cows, but fat content, FPR, EC and SCC were lower. TDMY was positively correlated with BCS and RFS. Milk hygiene and udder health indicators (SCC and EC) showed negative correlations with BCS and RFS. These results indicate that PG cows have low BCS and RFS, which can negatively affect some quantitative-qualitative milk parameters.

Keywords: Buffalo, Access to pasture, Confinement in barn, Welfare indicators, Milk components, Milk hygiene

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1. Introduction

Recently, the perceptions and priorities of producers and consumers regarding the quality assessment of animal-derived products have changed. These factors include not only milk yield and quality, but also management issues related to animal welfare, health, food safety, and consumer sensitivity (Costa et al., 2020; Okuyucu et al., 2024). Therefore, researchers have focused on improving the welfare, health, and quantitative-qualitative milk parameters of water buffaloes (*Bubalus bubalis*) due to the growing interest in water buffalo (hereafter buffalo) products (de la Cruz-Cruz et al., 2014; Atasever et al., 2020; Okuyucu et al., 2024).

Worldwide, buffalo cows are mostly raised under pasture-based farming conditions. However, the increase in demand for buffalo products has also led to the spread of semi-intensive and intensive farming conditions

(Akdağ et al., 2024). Although housing practices vary across countries, buffalo cows in Türkiye are generally confined in closed tied-stall or semi-open free-stall barns for part of the year or confined to these barns all year round (Okuyucu et al., 2024). In Türkiye, traditionally, grazing practices of natural pastures are dominant during certain periods of the year (Degirmencioğlu et al., 2015). Specifically, from April to November, the animals are kept in these barns and have access to grazing pastures (Atasever, 2022). Access to pasture or open spaces has long been recognized as having significant benefits for animal welfare, particularly in promoting hoof health and the expression of natural behaviours (Leso et al., 2023). These production patterns are varied and complex that they limit the stockperson's ability to monitor cow dry matter (DM) intake (DMI) and nutritional status. Therefore, in recent years, providing

buffalo cows with access to pasture has become a highly debated issue. This situation is related to whether the pastures can provide adequate and balanced nutrition for the buffaloes and this may negatively affect product quality and welfare (Leso et al., 2023). Several authors have reported that various factors can affect feed intake (DMI), animal behaviour and performance in grazing-based systems (Leso et al., 2023; Chiariotti et al., 2025). In particular, heat stress, low feed availability, and poor nutritional value can discourage buffalo cows from foraging. This can result in reduced productivity and decreased milk yield (Degirmencioğlu et al., 2015; Chiariotti et al., 2025). A study conducted on buffaloes in Türkiye reported that the quality of pastures offered to buffaloes may vary and that the milk fat and protein content of cows in intensive, semi-intensive and extensive production systems may vary (Yavrucu and Kılıç, 2021). Furthermore, during the early stages of lactation, the negative energy balance and mobilisation of body fat can result in frequent changes in the body condition score (BCS) and rumen fill scores (RFS) of cows (Saqib et al., 2022). This situation can lead to metabolic stress in cows, affecting their hematochemical profiles, health status, and thus quantitative-qualitative milk parameters (Burfeind et al., 2010; Saqib et al., 2022). Therefore, monitoring changes in feed intake and nutritional status in dairy cows during the early stages of lactation can help to assess their welfare and enable diseases to be diagnosed at an early stage (Burfeind et al., 2010; Bramley et al., 2013; Stadnik et al., 2017). The BCS and RFS, which are accepted as indicators of nutritional status and DMI in cows respectively, are important animal-based welfare indicators used in assessing animal welfare. BCS is an animal-based measurement used to subjectively visually assess the body fat and muscle condition of the cow. As with the BCS, RFS is an animal-based measurement in which the cow is evaluated subjectively. DMI is expressed as rumen fill, total liquid and DM content in the rumen (in kg), which depends on the composition, digestibility, and passage rate of the feed. Indeed, several studies have reported that reducing DMI can alter rumen fill levels (Burfeind et al., 2010), resulting in poor body condition in the long term (Atasever et al., 2020). This poor welfare status may increase the risk of metabolic disorders, such as mastitis (Bareille et al., 2003), metritis (Huzzey et al., 2007), and subclinical ketosis (Goldhawk et al., 2009). Furthermore, many studies have reported that poor body condition negatively affects milk quantity and quality traits (Saqib et al., 2022; Demirci and Okuyucu, 2025). In another study conducted on buffaloes, a positive correlation was determined between the BCS and RFS of the cows (Atasever et al., 2020). Therefore, during periods when buffaloes are kept in shelters and/or feeding control cannot be fully ensured (during periods when access to pasture is available), the systematic use of subjective assessment methods such as body and rumen fill status is important for the buffalo milk industry.

According to the literature survey, there is limited information available on animal welfare assessment criteria such as body condition and rumen fill, which are widely accepted as indicators of buffalo nutritional status (Atasever et al., 2020; Saqib et al., 2022). Therefore, further studies are necessary to comprehensively examine the relationships between these welfare assessment criteria (BCS and RFS) and milk quantity and quality traits. In this study, it was hypothesised that grazing cows (pasture-grazing, PG) and cows confined to a barn (no grazing, NG) would have different BCS and RFS values, and that this would affect quantitative-qualitative milk parameters. The present study aimed to investigate the effects of PG and NG management practices on BCS, RFS, the test-day milk yield (TDMY), milk components [dry matter, (DM), fat, solids non-fat (SNF), protein, fat-to-protein ratio (FPR), lactose and mineral)], milk physical properties [density, freezing point (FP), pH, electrical conductivity (EC)] and somatic cell count (SCC) in primiparous Anatolian buffalo cows.

2. Materials and Methods

This study was conducted on a total of 72 buffalo cows in two barns on a commercial farm in Samsun province, Türkiye: the first barn (fist group) was pasture-grazing (PG, n=36) and the second barn (second group) was non-pasture-grazing (NG, n=36). The observations and sample collection were performed twice at 7-day intervals on cows with days in milk (DIM) ranging from 70 to 94. Both PG and NG cows were housed in semi-open free-stall barns, where they were fed a total mixed ration (TMR) twice daily and milked once a day. In both barns, TMR with a 60:40 dry-matter ratio of roughage consists of alfalfa hay, wheat straw, maize silage and concentrate. PG cows grazed in the pasture between 10:00 a.m. and 18:00 p.m., having fed on TMR for approximately one hour after morning milking. However, the cows were allowed access to the pasture for grazing before they had completely consumed the TMR offered at the morning feeding. The cows were fed the same TMR again in the evening when they returned from the pasture to the barn. NG cows were kept in the barn continuously and fed the same TMR twice a day, but they were not allowed to graze. While NG cows were not subjected to air conditioning processes such as artificial showers, fountains, fogging and artificial ponds, PG cows were allowed to cool off in a natural lake in the pasture.

The milking procedures on both barns were identical and did not interfere with their routine practices. All cows were milked using a portable milking machine between 05:00 AM and 08:00 AM (PLS-2/1, Sezer, Bursa, Türkiye). To ensure good milking hygiene, the cows' udders were washed with warm water and dried with a clean, single-use cloth before milking. To facilitate milk flow and provide the necessary pre-stimulation, PG and NG cows suckled their own calves for one minute. Then, teat cups were attached and the milking process was completed. During milking, calves were kept close to the cows and

the milking process was carried out individually for each cow. To determine the TDMY of each cow, the milk collected in a tarred bucket after milking was weighed on an electronic scale (recorded in kg). Throughout the trial, each cow was milked individually, and a 50 ml sample was taken homogeneously from the milk collected in the bucket. Then, a homogeneous 50 ml sample was taken from the milk collected in the tarred bucket.

To evaluate the milk components, it was transported to the breeding laboratory at Ondokuz Mayıs University in a cold chain bag maintained at +4 °C. All milk components parameters were measured at temperatures between 32 °C and 35 °C. The percentages of DM, fat, SNF, protein, lactose and minerals, as well as milk density (mg/mL) and FP (°C), were analysed using an automatic milk analyser (Lactostar, Funke-Gerber, Germany). Additionally, the FPR was calculated as a percentage of fat to protein. Milk EC (mS/cm) and pH were measured using a FiveEasy Plus (Mettler Toledo, Switzerland), which was equipped with a conductivity sensor and a calibrated pH meter (Testo 205 pH meter, Lenzkirch, Germany), respectively. To calculate SCC per millilitre of milk, a DeLaval Cell Counter (DCC; DeLaval International AB, Tumba, Sweden) device, which is commercially available, and single-use cassettes manufactured specifically for the device were used. Milk samples were drawn into cassettes containing propidium iodide (PI), a fluorescent dye, using the cassette's piston (Sahin et al., 2014).

In the assessment of welfare parameters, body condition and rumen fullness were assessed by a single trained observer. The cows were standing with all four legs at the same level during the visual scoring of body condition and rumen fill. RFS was scored from the left hind side of the cow based on rumen fill rate and appearance of the paralumbar fossa. Rumen fullness was estimated using a visual assessment of the paralumbar fossa, adapted from by Burfeind et al. (2010) and Schneider et al. (2022), on a scale of 1 to 5 (Table 1). As previously explained Anitha et al. (2011), the BCS were subjectively scored on a five-point scale: 1= emaciated; 2 = thin; 3 = average; 4 = fat; 5 = obese. Half or quarter scales were used when necessary for body condition and rumen fullness observations (e.g. 2.50 or 3.75; Atasever et al., 2020). No additional feed was offered to the cows during milking on farm, and all observations and scoring were performed at this time. All cows were fed TMR once the milking process was complete.

All statistical analyses were performed using SPSS (version 21.0, SPSS Inc., Chicago, IL, USA). The welfare parameters (BCS and RFS) and quantitative-qualitative milk parameters of the PG and NG groups were compared using the Mann–Whitney U test and *t-test*, respectively. Before analysing the data, Kolmogorov-Smirnov and Levene's tests were applied to assess normality and homogeneity of variance in the data obtained from the recordings of the test days (P>0.05). Since the SCC data did not follow a normal distribution, a logarithmic transformation was applied to the data; however, the actual data were presented. Furthermore, spearman correlation analysis was used to examine the mutual relationship between welfare parameters (BCS and RFS) and quantitative-qualitative milk parameters (Önder, 2018).

3. Results

The cows' BCS ranged from 2.50 to 3.75, while their RFS ranged from 1.50 to 3.50. Based on the results of the non-parametric the Mann–Whitney U test, there was a significant effect of PG and NG management practices on the BCS and RFS of primiparous Anatolian buffalo cows (Table 2). The BCS of the NG cows was higher than that of the PG cows (P=0.003). Similarly, the RFS of the NG cows was higher than that of the PG cows (P<0.001).

Table 3 shows that in primiparous Anatolian buffalo cows, the PG and NG management practices affected some quantitative-qualitative milk parameters. The NG cows had a higher TDMY (P<0.001) and protein content (P=0.003), but lower fat (P<0.001), FPR (P=0.001), EC (P=0.001) and SCC (P=0.005) than the PG cows.

In the current study, there was a positive correlation between BCS and RFS (r=0.581; P=0.01). Furthermore, significant correlations were found between the quantitative-qualitative milk parameters, and the BCS and RFS of the cows (Table 4). The qualitative milk parameters (TDMY) were positively correlated with the BCS (r=-0.173; P<0.001) and RFS (r=0.262; P=0.002). The quantitative milk parameters, such as mineral (r=0.407; P=0.038), SCC (r=-0.259; P=0.002) and EC (r=-0.196; P=0.018), were negatively correlated with the BCS. Similarly, the RFS displayed a negative correlation with the SCC (r=-0.236; P=0.004) and EC (r=-0.219; P=0.008).

Table 1. Rumen fill scores of buffalo cows based on the appearance of the paralumbal fossa (Burfeind et al., 2010)

Score	Appearance of para-lumbar fossa	
	The transverse processes	The last rib
1	If hand-width cavitates form inside under the transverse processes,	If there is a cavitates the width of a hand behind the last rib,
2	If there are cavitates less than a hand's width under the transverse processes,	If there is a cavitates the width of a hand behind the last rib,
3	If it falls downwards by about the width of a hand and then bulges outwards,	If there is less than a hand's width of cavitates behind it,
4	If there arch outwards immediately below it,	If the skin covers the area behind it,
5	If transverse processes are not visible,	If the last rib is not visible,

Table 2. Mean the BCS and RFS of PG and NG cows

Welfare Parameters	Groups	Statistics						
		n	Mean	Median	Min-max	SEM	Z	P-value
BCS	NG	72	2.98	3.00[a]	2.50-3.75	0.033	-2.954	0.003
	PG	72	2.85	2.75[b]	2.50-3.75	0.022		
RFS	NG	72	2.60	2.50[y]	2.00-3.50	0.500	-5.481	< 0.001
	PG	72	2.21	2.00[z]	1.50-3.00	0.036		

SEM= standard error of the mean, PG= pasture-grazing, NG= cows confined to a barn and no grazing, BCS= body condition score, RFS= rumen, fill score, [a-b] mean values in the same column with different superscripts differ (P<0.05) for BCS, [y-z] mean values in the same column with different superscripts differ (P<0.05) for RFS.

Table 3. Mean quantitative-qualitative milk parameters of PG and NG cows

Variables	NG	PG	SEM	P-Value
Milk yield trait				
TDMY	3.34	3.08	0.342	< 0.001
Milk component (%)				
DM	18.21	18.76	0.156	0.078
Fat	7.85	8.58	0.101	< 0.001
SNF	10.36	10.18	0.097	0.359
Protein	4.57	4.24	0.570	0.003
FPR	1.75	2.08	0.036	0.001
Lactose	4.97	4.93	0.048	0.717
Mineral	0.66	0.67	0.001	0.451
Milk physical trait				
Density (mg/ml)	1.033	1.034	0.0001	0.918
FP (°C)	-0.549	-0.555	0.0061	0.590
EC (mS/cm)	3.44	3.67	3.572	0.001
pH	6.54	6.55	0.018	0.766
SCC (x10³)	63.90	102.94	7.030	0.005

SEM= standard error of the mean, PG= pasture-grazing, NG= cows confined to a barn , and no grazing, TDMY= test-day milk yield, DM= dry matter, SNF= non-fat solid, FPR= fat-to-protein ratio, FP= freezing point, SCC= somatic cell count, EC= electrical conductivity.

Table 4. Correlations between quantitative-qualitative milk parameters and specific welfare assessment criteria (BCS and RFS)

İtems		BCS	RFS
TDMY	r/r^s	0.407	0.262
	(P)	P < 0.001	P = 0.002
DM	r/r^s	0.136	0.063
	(P)	P = 0.105	P = 0.452
Fat	r/r^s	0.137	0.050
	(P)	P = 0.100	P = 0.555
SNF	r/r^s	0.073	0.047
	(P)	P = 0.381	P = 0.575
Protein	r/r^s	0.135	0.110
	(P)	P = 0.107	P = 0.188
FPR	r/r^s	-0.025	-0.058
	(P)	P = 0.765	P = 0.490
Lactose	r/r^s	0.060	0.063
	(P)	P = 0.474	P = 0.453
Density	r/r^s	-0.111	-0.09
	(P)	P = 0.231	P = 0.273
FP	r/r^s	0.135	0.161
	(P)	P = 0.107	P = 0.054
Mineral	r/r^s	-0.173	-0.14
	(P)	P = 0.038	P = 0.463
SCC	r/r^s	-0.259	-0.236
	(P)	P = 0.002	P = 0.004

Table 4. Correlations between quantitative-qualitative milk parameters and specific welfare assessment criteria (BCS and RFS) (continue)

İtems		BCS	RFS
pH	r/r$_s$	-0.090	-0.010
	(P)	P = 0.283	P = 0.988
EC	r/r$_s$	-0.196	-0.219
	(P)	P = 0.018	P = 0.008

BCS= body condition score, RFS= rumen fill score, TDMY= test-day milk yield, DM= dry matter, SNF= non-fat solid, FPR= fat-to-protein ratio, FP= freezing point, SCC= somatic cell count, EC= electrical conductivity.

4. Discussion

These results reveal that PG and NG practices has a significant effect on buffalo cows' BCS and RFS, as well as on the quantitative-qualitative milk parameters. Furthermore, the scores related to body condition and rumen fill affected by the examined factors and the correlation between the examined variables (TDMY, mineral, SCC and EC) are also important. These results may contribute to a better understanding of how PG and NG practices affect BSC and RFS, which are considered indicators of cows' feeding and DMI status, and their relationship with milk parameters (Burfeind et al., 2010; Anitha et al., 2011; Schneider et al., 2022).

In the current study, it was noteworthy that NG cows had higher BCS and RFS values than PG cows, and that cows in this group had higher TDMY and protein content, while having lower fat content, FPR, EC, and SCC values. The significant correlation observed between BCS and RFS reflects that these are the primary individual welfare parameters that can be used to determine the nutritional status of cows. A positive correlation between BCS and RFS, which is accepted as an indicator of DMI was consistent with the findings of Atasever et al. (2020). The higher BCS and RFS of PG cows compared to NG cows suggests that pasture grazing does not provide cows with sufficient DMI. Although the current study did not determine the quality and nutritional composition of the pasture, the findings can be associated with differences in pasture type and grass height (Castelán-Ortega et al., 2018), low feed availability and low nutritional value, which can affect the DMI of cows in the pasture (Drescher et al., 2006; Degirmencioğlu, et al., 2015; Chiariotti et al., 2025). However, the present findings cannot be explained solely by this hypothesis. In the present study, cows grazing on pasture were required to walk several kilometres to reach the milking parlour. This increased demand for locomotion may partially explain the lower BCS observed in PG cows, as the additional energy expenditure associated with prolonged walking could have contributed to greater mobilisation of body reserves (Maurya et al., 2012; Neave et al., 2021).

The low BCS and RFS of PG cows confirm that their nutrient requirements are not being adequately satisfied, resulting in low TDMY and protein content. Changes in blood metabolite levels in cows with low BCS are probably negatively affecting milk synthesis in the mammary gland (Saqib et al., 2022). This study confirms these statements, as the milk yield and protein content of PG cows with low BCS values are lower. Furthermore, as Schneider et al. (2022) stated, the negative correlation between milk yield and RFS is consistent with the results of this study. Contrary to these findings, another noteworthy finding was that PG cows had higher fat, FPR, EC, and SCC values than NG cows. Under the current study conditions, the PG cows had access to a wet area, whereas the NG cows did not have access to any artificial showers, sprinklers or ponds. This may have protected the PG cows from heat stress to a greater extent than the NG cows during the study period, which ran from May to August (Okuyucu, 2025a). Especially, the ability of PG cows to exhibit behaviours related to heat regulation, such as wallowing in mud, may have reduced their heat stress (Chiariotti et al., 2025). The higher milk fat and FPR levels in the PG cows suggest that they were not exposed to heat stress at levels that could have had a negative impact on milk synthesis. However, the design of the current study did not allow this hypothesis to be confirmed. Therefore, further studies are needed to confirm this. Apart from all these hypotheses, the high SCC and EC values in PG cows, which will be discussed later in the present findings, may have caused the low milk fat content and FPR determined in this group. Indeed, many authors have confirmed that fat (Okuyucu, 2025b) and lactose (Rajčević et al., 2003) decrease as SCC and EC values increase (Aytekin and Boztepe, 2014). Therefore, it is an expected finding that milk components are negatively affected in PG cows with high SCC.

It was also notable that PG cows had higher milk EC and SCC values than NG cows. These results indicate that although access to pasture allows buffalos to be raised in natural habitats, udder health may be negatively affected in uncontrolled environmental conditions. This situation can be explained by the fact that PG cows that graze in wet areas are more likely to experience udder contamination. Although the design of the current study did not allow for an assessment of the cows' body hygiene status, it is thought that access to pasture may have increased the risk of body contamination, thus increasing SCC and EC values (Schreiner and Ruegg, 2003; Erdem and Okuyucu, 2019). Therefore, further studies are needed to assess the body hygiene status of cows with access to pasture. Indeed, many authors have confirmed that contamination factors (poorly designed facilities in housing system, dirty bedding or ground,

thermoregulation habits, including wallowing in the mud) can affect the health of the udder and the hygiene of the milk (Saber, et al., 2017; Robles et al., 2021; Chiariotti et al., 2025).

5. Conclusion

The current study showed that cows confined to barns or not grazing on pasture (NG group) improved BCS, RFS, milk yield, and milk protein content, while cows with access to pasture (PG group) increased milk fat and FPR. Furthermore, indicators of udder health and milk hygiene status (lower SCC and EC) were also improved in cows confined to barns. These results demonstrate that both rearing conditions have advantages and disadvantages. On farms where restriction-based production systems can be implemented, offering free-choice pasture access to cows, allowing them to exercise their own preferences and combine the benefits of both barns and pasture, can improve their welfare parameters and productivity. Therefore, further studies are needed to examine welfare parameters such as body hygiene and lameness, as well as quantitative-qualitative milk parameters in extensive and semi-intensive production systems with pasture access.

Author Contributions

The percentages of the authors' contributions are presented below. All authors 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 authors declared that there is no conflict of interest.

Ethical Consideration

The experimental procedures were approved by the Animal Ethics Committee of Ondokuz Mayis University (approval date: December 25, 2025; protocol code: 2025/90).

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