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Original study

Effects of birth weight and growth traits on the first lactation milk yield and reproduction characteristics in Anatolian buffaloes

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Abstract. This study aimed to reveal the effects of birth weight (BW), 6-month live weight (LW_6), and 12-month LW (LW_{12}) on first lactation milk yield and reproduction characteristics and to determine the non-genetic factors affecting these traits of Anatolian buffaloes in Amasya Province. For this purpose, 200 Anatolian buffaloes born between 2014 and 2018 and calved between 2017 and 2021 formed the basis of this study. These animals were divided into two groups with respect to BW ($<$ 26.82 and $\geq$ 26.82 kg), LW_6 ($<$ 88.00 and $\geq$ 88.00 kg), and LW_{12} ($<$ 138.47 and $\geq$ 138.47 kg). The effect of birth year on BW ($P = 0.044$), LW_6 ($P < 0.001$), and LW_{12} ($P < 0.001$) was statistically significant, while there was no significant effect of birth season on BW and LW_6 ($P > 0.05$), except LW_{12} ($P < 0.001$). The effect of dam age on LW_6 was significant ($P = 0.039$), except BW and LW_{12} ($P > 0.05$). In the present study, only the BW groups had a significant effect on lactation length (LL) ($P = 0.006$). The effect of growth traits on the first calving age (FCA) of the LW_{12} group was significant ($P = 0.036$). Although it was not statistically significant, it can be said that buffaloes with higher LW in terms of BW and growth traits had higher lactation milk yield (LMY), earlier FCA, and shorter calving intervals (CIs). There have been limited studies on the effects of BW and growth traits on milk and reproduction traits in buffaloes, and most of the studies were conducted in cattle. Therefore, more studies are required to reveal the relationships between related traits in buffaloes.

1 Introduction

The presence of buffaloes in Türkiye dates back to 3000 BCE (Alkoyak and Öz, 2022). The buffaloes raised in Türkiye, known as Anatolian buffaloes, originate from Mediterranean buffaloes, a subgroup of riverine buffaloes (Kul et al., 2016; Soysal et al., 2018). Buffaloes in Türkiye are bred for milk and meat production (Atasever and Erdem, 2008). In addition to their resistance to diseases and harsh environmental conditions, buffaloes are valued for their efficiency in converting low-quality feed into high-quality milk and meat, as well as for their lower husbandry costs compared to dairy cattle (Atasever and Erdem, 2008; Kul et al., 2016). These animals are typically black or dark gray with horns that curl upward, bending backward or to the sides (Soysal et al., 2018; Koçak et al., 2019). Buffaloes are distributed across Türkiye, where the majority of the national population resides (Alkoyak and Öz, 2022). The water buffalo population in Türkiye was an important genetic resource with approximately 161 749 heads in 2023 (TUIK, 2024). Buffalo breeding in Türkiye is predominantly practiced in small-scale family farms, with a few larger commercial operations (Koçak et al., 2019).

In the continuity of a herd, the age of the heifer has an impact on their subsequent reproduction and milk yield performance. In this respect, the process from birth to the first calf should be well managed (Göncü, 2020). In this manner, the herd size will be maintained, and genetically superior heifers will be selected for the continuation of the herd (Mourits et al., 1999). Minimizing calf mortalities, which result in production losses, and increasing the growth performance of young animals that create high vitality and future generations always remain important for economical production (Yüceer and Özbeyaz, 2010). Buffalo heifers gain faster to begin their physiological processes earlier for reproduction and milk production (Yadav et al., 2001). Therefore, increasing milk and fertility performance are closely related to the growth performance of young animals from birth to adulthood.

Birth weight (BW), which is the first observable polygenic characteristic of the animal, is the first phenotypic indicator of the genotype and is a critical feature for subsequent growth (Yadav et al., 2001). In addition to the BW of the buffalo, its growth rate also plays a significant role in determining its health and production traits in later years. Understanding the relationships between calf growth characteristics and future productivity and identifying influencing factors will facilitate the development of the best herd management strategies to optimize calf growth and to select heifers based on early-life measurements (Wathes et al., 2008). The BW of buffaloes is affected by non-genetic factors such as dam age (Thiruvenkadan et al., 2009), season (Hossein-Zadeh et al., 2012), and year (Akyol, 2023). The animal's actual genetic potential for growth may be suppressed by these factors.

High BW positively affects subsequent lactation milk yield (LMY; Hoffman, 1997). However, increasing the feeding level during the breeding period causes a decrease in subsequent milk yield by causing fat accumulation rather than skeletal and epithelia tissue growth due to heavier heifers at first calving, negatively affecting udder development (Mourits et al., 2000). Because mammary gland development mostly occurs before calving, a younger calving age also leads to reduced milk yield due to poor mammary tissue development (Serjsen, 2005).

The obtained data regarding the effects of BW, growth characteristics, and first calving age (FCA) on the subsequent performance of buffaloes have been incompatible. In addition, the number of studies revealing the effects of BW and growth characteristics on productivity traits has been quite limited. These kinds of studies were mostly conducted in cattle. In the present study, we aimed to reveal the effects of BW and 6-month live weight (LW_6) and 12-month LW (LW_{12}) of Anatolian buffaloes on the first LMY and reproduction traits and to determine the effects of non-genetic factors on these traits.

2 Materials and methods

This study was conducted with 200 Anatolian buffaloes born from 2014 to 2018 and calved from 2017 to 2021 within the scope of the Public Anatolian Buffalo Breeding Project conducted in Amasya Province.

The birth date, sex, dam number, and other identifying information of the calves were recorded within 24 h by using the Buffalo Star recording program. The weights of the calves were measured on the day they were born by using a hand scale. After the calves were marked with ear tags, all data were recorded by using the Buffalo Star software developed for the Public Anatolian Buffalo Breeding Project (Tekerli, 2015–2018). The LW_6 and LW_{12} of calves were determined and recorded to compute LW_6 and LW_{12} using linear interpolation.

Monthly milk yields of all buffaloes were recorded during lactation. Daily milk yield (DMY), lactation milk yield (LMY), and lactation length (LL) were obtained. During the study, data regarding calving date, first calving age (FCA), and second calving age were entered into the this program to calculate the FCA, calving interval (CI), and dry period (DP).

Effects of birth year, birth season, and dam age on BW, LW_6, and LW_{12} were evaluated by using the following linear model:

$$Y_{ijkl} = \mu + a_i + b_j + c_k + e_{ijkl}, \quad (1)$$

where Y_{ijkl} is the dependable variable, μ the overall mean, α_i the effect of birth year (i: 2014, 2015, 2016, 2017, 2018), b_j the j effect of birth season (j: winter, spring, summer, autumn), c_k the k effect of dam age (k: younger: 2, 3, 4; moderate: 5, 6, 7; older: 8, 9, $\geq$ 10 ages), and e_{ijkl} the random error.

Groupings for BW, LW_6, and LW_{12} were based on their means. The first group was below the average; the second group was above the average. To evaluate the effects of BW, LW_6, and LW_{12} on milk yield and reproduction traits, the following linear model was applied:

$$Y_{ijkl} = \mu + a_i + b_j + c_k + e_{ijkl}, \quad (2)$$

where Y_{ijkl} is the dependable variable, μ the overall mean, α_i the i effect of BW (i: < 26.82 kg, ≥ 26.82 kg), b_j the j effect of LW_6 (j: < 88.00 kg, ≥ 88.00 kg), c_k the k effect of LW_{12} (k: < 138.47 kg, ≥ 138.47 kg), and e_{ijkl} the random error.

Normality analyses performed with Shapiro–Wilk and Kolmogorov–Smirnov tests satisfied the assumptions ($P > 0.05$). Furthermore, the homogeneity of the variances was established by the Levene test ($P > 0.05$). In the study, a general linear model analysis was used to statistically compare three groups, and a t test was used to compare two groups. Differences between subgroups were compared using Duncan's multiple-range test. In addition, Pearson correlation coefficients were calculated in the study. The data were analyzed using SPSS 17 for Windows.

3 Results and discussions

The effects of birth year, birth season, and dam age on BW, LW_6, and LW_{12} are given in Table 1. The effect of birth year was significant on BW ($P = 0.044$), LW_6 ($P < 0.001$), and LW_{12} ($P < 0.001$). The highest BW of calves was determined in 2017 and the lowest in 2014. There was no significant difference between the BWs of those whose birth years were 2015, 2016, and 2018. The highest LW_6 and LW_{12} were observed in 2016 ($P < 0.001$). There was no significant difference between the LW_6 data, except for 2016. The lowest LW_{12} was determined in 2014 and 2015. In this study, the variations in BW and growth characteristics across different years reflect the influence of farm management practices and environmental conditions. Animals born later in the data collection period exhibited higher body weights, suggesting improved farm management over time. Management quality often varies with factors such as farmer expertise, farming methods, selection criteria, and stocking density (Alkoyak and Öz, 2022). The year of birth effect is likely attributable to differences in herd size, environmental factors, management strategies, fodder availability, and breeding plans (Sadek et al., 2014). These findings were expected, given that pasture-based feeding in rural settings depends heavily on climatic conditions affecting pasture growth and feed availability. Similar results were reported for BW in buffaloes (Thiruvenkadan et al., 2009; Hossein-Zadeh et al., 2012; Akyol, 2023), LW_6 (Thiruvenkadan et al., 2009; Akyol, 2023), and LW_{12} (Akyol, 2023).

There were conflicting results, indicating that the birth year had no effect on the BW of Egyptian buffalo (Marai et al., 2009) and on the LW_{12} of Surti buffalo (Pandya et al., 2015).

In the current study, while there was no significant effect of birth season on BW ($P = 0.065$) and LW_6 ($P = 0.348$), LW_{12} was affected by birth season ($P < 0.001$). The highest LW_{12} was determined in calves born in the summer, but no significant difference was determined between the LW_{12} of those born in other seasons. Although the differences were not statistically significant, calves born in the summer season, whose mothers grazed on spring–summer pastures during the late stages of pregnancy and the nursing period, exhibited higher BW and LW_6. Calves born in the summer also had higher LW_{12}, likely due to grazing directly on spring and summer pastures post-weaning. This finding can be attributed to favorable temperatures and the availability of high-quality green fodder during these seasons (Uğurlu et al., 2016). As expected, the rainy season provides more abundant and higher-quality pasture, enhancing growth traits in buffaloes (Segura-Correa et al., 2017). In Amasya Province, buffaloes are kept indoors and tied during winter, preventing winter-born buffaloes from grazing (Koçak et al., 2019). Additionally, pasture quality declines during autumn, a transitional period (Kul et al., 2018). The results obtained in this study were similar to those of previous studies on BW (Thiruvenkadan et al., 2009; Akkulak and Kul, 2023), LW_6 (Thiruvenkadan et al., 2009), and LW_{12} (Akkulak and Kul, 2023) in buffaloes. In detail, the birth season had significant effects on BW (Hossein-Zadeh et al., 2012; Kul et al., 2018) and LW_6 (Akkulak and Kul, 2023) in buffaloes. Thiruvenkadan et al. (2009) reported that the LW_{12} in Murrah buffaloes was not affected by the season of birth, unlike the current study. Erdem et al. (2015) reported that both BW and LW_6 of Anatolian buffaloes were the highest in autumn ($P < 0.001$). Marai et al. (2009) observed the lowest BW in Egyptian buffalo calves born in summer. Kul et al. (2018) determined the lowest BW in Anatolian buffalo calves born in autumn and the highest in summer.

Dam age affected LW_6 significantly ($P = 0.039$) but not BW ($P = 0.194$) and LW_{12} ($P = 0.162$). LW_6 was observed to be the highest in the calves of younger dams in the first age group but the lowest in the second age group (Table 1). The present results are similar to those of Erdem et al. (2015). These results can be explained by the fact that young buffaloes, still growing towards their adult size, may further the development of the fetus during pregnancy (Kul et al., 2018). However, the selection of young buffaloes with superior growth traits for the purpose of projects, their heavier calves, and improvements in the care and feeding practices at farms are believed to have influenced these outcomes. However, this finding disagrees with those of Hossein-Zadeh et al. (2012) and Kul et al. (2018) in that the effect of dam age on BW was significant. This finding was not consistent with the results of Erdem et al. (2015), who reported that the effect of dam age on LW_{12} in Anatolian buffaloes was significant. Hossein-Zadeh et al. (2012) determined that older dams had heavier buffalo calves. In our study, without statistical significance, the BW, LW_6, and LW_{12} of the calves born from younger dams were higher.

In buffaloes, LMY and LL are important indicators of their genetic potential (Verma et al., 2021). A DP is crucial for buffaloes as it allows the animal to rest and repair udder tissue, thereby preparing for the next lactation. This rest period is essential for maximizing milk production in the following lactation cycle (Eldawy et al., 2021). As shown in Table 2, the BW of calves had a significant effect on the LL ($P = 0.006$), whereas other milk yield traits were not affected by growth traits. These findings demonstrate that LL increased with increasing BW. Although it was not statistically significant ($P > 0.05$), it was seen that the LMY values of calves with higher BW, LW_6, and LW_{12} were higher than those of lighter ones.

According to several studies, growth rate in the early stages of life has a positive effect on subsequent milk yield (Hoffman, 1997). Carson et al. (2002) determined that heavier Holstein Friesian heifers before the first calving had higher milk yield. This can be explained by the better development of udder tissue in heavier heifers (Serjsen, 2005). The results obtained in this study are similar to those obtained by Heinrichs and Heinrichs (2011), who reported that dairy calves with a faster growth had higher LMY at the first lactation. In contrast to these results, Mourits et al. (2000) indicated that more fat accumulation in the udder tissue of heavier dairy heifers adversely affects udder development and leads to a decrease in subsequent milk yield. The results

Table 1. Effects of non-genetic factors on BW, LW_6, and LW_{12} (mean ± SE).

		N	BW	N	LW_6	N	LW_{12}
Birth year	P value		0.044		< 0.001		< 0.001
	2014	39	25.21 ± 0.61^{b}	42	88.47 ± 2.90^{b}	42	129.74 ± 3.44^{c}
	2015	51	26.97 ± 0.73^{ab}	51	82.19 ± 1.71^{b}	49	130.77 ± 2.12^{c}
	2016	41	27.42 ± 0.71^{ab}	42	102.53 ± 4.09^{a}	42	153.89 ± 4.01^{a}
	2017	35	27.83 ± 1.04^{a}	35	82.70 ± 3.20^{b}	35	141.30 ± 3.80^{b}
	2018	30	26.67 ± 0.72^{ab}	30	83.08 ± 1.76^{b}	30	138.39 ± 2.26^{bc}
Birth season	P value		0.065		0.348		< 0.001
	Winter	31	26.55 ± 0.86	34	86.27 ± 2.80	33	135.95 ± 3.04^{b}
	Spring	72	26.04 ± 0.61	74	87.25 ± 2.31	74	131.70 ± 2.32^{b}
	Summer	78	27.92 ± 0.52	77	90.71 ± 2.51	76	146.50 ± 2.84^{a}
	Autumn	15	25.42 ± 1.02	15	81.74 ± 3.33	15	136.79 ± 3.96^{b}
Dam age	P value		0.194		0.039		0.162
	1 (2–4 ages)	51	27.61 ± 0.62	53	93.38 ± 3.10^{a}	53	140.50 ± 3.41
	2 (5–7 ages)	83	26.97 ± 0.56	85	85.05 ± 1.83^{b}	83	134.96 ± 2.16
	3 (8–≥10 ages)	62	25.98 ± 0.62	62	87.45 ± 2.58^{ab}	62	141.44 ± 2.86
Overall		196	26.82 ± 0.35	200	88.00 ± 1.40	198	138.47 ± 1.57

[a,b,c] Different superscripts in the same column denote significance ($P < 0.05$). BW: birth weight; LW_6: 6-month live weight; LW_{12}: 12-month live weight.

of this study are different from those of other studies for the following reasons: the studies were conducted on different breeds in different countries and regions, and there were differences in herd management practices between dairy farms.

As seen in Table 2, the LW_{12} group had a significant effect on FCA ($P = 0.036$), but the CI was not affected by any of growth traits ($P = 0.296$). In addition, the FCA was calculated to be higher in buffaloes with a lighter LW_{12} (first group). The growth performance of buffaloes raised by smallholder farmers is a critical and vulnerable factor (Bayou et al., 2015). Low live weights during early lactation can decrease the likelihood of pregnancy at the first insemination due to insufficient energy needed for ovarian activity and estrus (Eldawy et al., 2021). Additionally, lighter Holstein heifers reach puberty later than heavier ones (Sadek et al., 2014). Heavier heifers likely have more mature reproductive tracts due to alternating estradiol and progesterone peaks after reaching puberty (López et al., 2018). These findings suggest that achieving adequate skeletal maturity through proper early growth is essential for successful calving in heifers (Cooke et al., 2013). One possible explanation for discrepancies in growth rates, associated with reduced FCA and CI, is physiological immaturity at the time of first breeding (Brickell et al., 2009). Further research is needed to confirm the impact of BW and early growth on subsequent fertility and productivity.

The CI has great economic importance and is closely related to LMY and LL (Verma et al., 2021). Shortening the first CI will contribute to shortening the generation interval and increasing the genetic progress of the herd (Muasya et al., 2013). It will also reduce management costs such as feed and labor (Tozer and Heinrichs, 2001).

FCA is a crucial factor in determining the length of a nonproductive period and influencing subsequent fertility (López at al., 2018). FCA is strongly influenced by the growth rate, which generally has high heritability in Italian Holsteins (Verma et al., 2021). Pirlo et al. (2000) reported that a decrease in the FCA adversely affected the first LMY in Italian Holsteins, associated with low BW in young heifers at the beginning of the first lactation. Boopathi et al. (2021) found that BW did not significantly affect reproductive performance in Murrah buffaloes. Eldawy et al. (2021) determined that the effects of BW on the FCA and CI of Egyptian buffaloes were significant ($P < 0.05$). Akbulut et al. (1998) found that the FCA was significantly affected by BW, LW_6, and LW_{12} in Brown Swiss cattle ($P < 0.05$). Ettema and Santos (2004) did not see the effect of FCA on subsequent reproductive performance of Holstein cows, and more studies need to be conducted on this subject. This difference may be attributed to various management and environmental conditions, herd and farm sizes, variations in feed and fodder availability, and the sires used for breeding and their genetic potential (Kul et al., 2018).

The correlation analysis (Table 3) showed that there was a positively low correlation between BW and milk yield characteristics ($0.026 \le r \le 0.134$; $P > 0.05$), except for the DP ($r = -0.146$, $P > 0.05$). According to the findings obtained in this study, the correlation between the LW_{12} and FCA was negative (with statistical significance $r = -0.148$, $P = 0.037$), whereas there was an insignificant correlation be-

Table 2. Changes in milk yield and reproduction traits according to BW, LW_6, and LW_{12} groups (mean ± SE).

		Milk yield traits								Reproduction traits			
		N	LMY (kg)	*N*	LL (d)	*N*	DMY (kg)	*N*	DP (d)	*N*	FCA (month)	*N*	CI (d)
BW	*P* value		0.130		0.006		0.914		0.110		0.369		0.085
	1 (< 26.82 kg)	103	918.55 ± 15.15	103	209.07 ± 2.14^{b}	103	4.40 ± 0.06	21	250.43 ± 28.68	110	42.92 ± 1.24	21	443.05 ± 25.86
	2 (≥ 26.82 kg)	78	953.35 ± 15.98	78	218.35 ± 2.45^{a}	77	4.39 ± 0.07	20	212.30 ± 24.53	86	42.10 ± 1.27	20	432.55 ± 23.26
LW_6	*P* value		0.585		0.755		0.203		0.080		0.345		0.183
	1 (< 88.00 kg)	113	930.09 ± 13.90	113	214.64 ± 2.01	113	4.34 ± 0.06	24	227.96 ± 27.82	123	42.36 ± 1.03	24	434.96 ± 24.09
	2 (≥ 88.00 kg)	72	939.33 ± 17.69	72	210.93 ± 2.76	71	4.48 ± 0.08	18	218.33 ± 24.77	77	43.68 ± 1.63	18	427.17 ± 24.36
LW_{12}	*P* value		0.271		0.549		0.556		0.398		0.036		0.296
	1 (< 138.47 kg)	116	918.79 ± 13.21	116	211.58 ± 2.07	115	4.36 ± 0.06	25	233.16 ± 28.78	124	44.08 ± 1.21^{a}	25	442.76 ± 26.72
	2 (≥ 138.47 kg)	67	953.44 ± 18.87	67	215.21 ± 2.68	67	4.44 ± 0.08	16	209.94 ± 21.75	74	40.51 ± 1.24^{b}	16	413.38 ± 16.53

[a, b] Different superscripts in the same column denote statistical significance ($P < 0.05$). LMY: lactation milk yield; LL: lactation length; DMY: daily milk yield; DP: dry period. BW: birth weight; LW_6: 6-month live weight; LW_{12}: 12-month live weight.

Table 3. Correlations among BW, LW_6, and LW_{12} with milk yield and reproduction traits.

	Milk yield traits				Reproduction traits	
	LMY (kg)	LL (d)	DMY (kg)	DP (d)	FCA (month)	CI (d)
BW	0.108	0.134	0.026	−0.146	−0.088	−0.047
	(0.147)	(0.071)	(0.724)	(0.362)	(0.222)	(0.773)
LW_6	−0.006	−0.099	0.079	−0.210	0.002	−0.210
	(0.934)	(0.180)	(0.288)	(0.181)	(0.978)	(0.182)
LW_{12}	0.057	0.077	0.009	−0.132	−0.148	−0.137
	(0.445)	(0.301)	(0.908)	(0.409)	(0.037)	(0.393)

LMY: lactation milk yield; LL: lactation length; DMY: daily milk yield; DP: dry period; FCA: first calving age; CI: calving interval; LW: live weight; BW: birth weight; LW_6: 6-month live weight; LW_{12}: 12-month live weight.

tween LW_6 and FCA ($r = 0.002$, $P > 0.05$). Positive correlation between BW and LMY ($r = 0.331$) in Anatolian buffaloes was observed by Akkulak and Kul (2023). In the same study, correlations between LW_6 with LMY ($r = 0.267$) and DMY ($r = 0.339$) were found to be positive. Yıldız et al. (2008) determined a negative and significant correlation between BW and LMY in Eastern Anatolian Red cows ($P < 0.05$). Akbulut et al. (1998) found insignificant negative correlations between 305 d milk yield and BW and LW_{12} and positive correlations with LW_6 in Brown Swiss cattle. Sorathiya et al. (2009) found negative correlations between the BW and FCA and between LW_6 and LW_{12} in Surti buffaloes. Naqvi and Shami (1999) did not determine any significant relationship between BW and the FCA of dams in Nili-Ravi buffalo calves ($P > 0.05$).

4 Conclusions

In the present study, the effects of some non-genetic factors on BW, LW_6, and LW_{12} were statistically significant. Therefore, it is essential to consider these factors (e.g., calving year, calving season, and dam age) in herd management practices. The effect of BW on LL and the effect of LW_{12} on the FCA were statistically significant. The LL of buffaloes with higher BW was longer, and the FCA of buffaloes with higher LW_{12} was shorter. It can be said that buffaloes with higher LW in terms of birth and growth traits had longer LL and earlier FCA. Although it was not statistically significant, LMY increased, and CI tended to decrease with increased LW. As seen in the studies conducted, the number of studies on the effects of BW and growth traits on milk and reproduction traits in buffaloes was limited, and most of the studies were conducted on cattle. Therefore, more studies with large numbers of animals are required to reveal the relationships between related traits in buffaloes.

Data availability. The research data from the study are available on request from the corresponding author.

Author contributions. SA and EK designed the study. SA collected the data. SA and EK carried out the statistical data analysis. SA and EK wrote the draft of the manuscript, SA reviewed the manuscript, and EK edited the manuscript. All authors contributed to the article and approved the submitted version.

Competing interests. The contact author has declared that neither of the authors has any competing interests.

Ethical statement. There was no direct contact with buffaloes, and all measurements were routine herd managements from farms; therefore, ethical approval was not required.

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