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Influence of calving age, parity, and calf gender on lactation metrics, reproductive and economic efficiency parameters in Egyptian buffaloes

Hadeel S. El-Qaliouby[1*], Nagwa I. El-Kasrawy[2], Hassaballah A. Abouelghait[3], Mohamed M. Hegazy[3], Ayman H. Abd El-Aziz[4]

[1]*Animal and Poultry Production, Animal Wealth Development Department, Faculty of Veterinary Medicine, Benha University, Toukh, 13637, Egypt.*
[2]*Veterinary Economics and Farm Management, Animal Wealth Development Department, Faculty of Veterinary Medicine, Damanhour University, Damanhour, 22511, Egypt.*
[3]*Mahallet Mousa Buffalo Research Station, Animal Production Research Institute, Agricultural Research Center, Ministry of Agriculture, Egypt.*
[4]*Animal and Poultry Breeding and Production, Animal Wealth Development Department, Faculty of Veterinary Medicine, Damanhour University, Damanhour, 22511, Egypt.*

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***Correspondence:**

Corresponding author: Hadeel S. El-Qaliouby
E-mail address: Hadil.abbas@fvtm.bu.edu.eg

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ABSTRACT

Buffalo reproductive performance and sustained productivity measures remain inadequately studied. This study aimed to investigate the influences of calving age, parity, and calf gender on specific indicators, including days in milk (DIM), daily milk yield (DMY), total milk yield (TMY), and 270-days milk yield (270-DMY), alongside reproductive and economic parameters. Analyzing 2112 buffalo cow datasets from 1994-2022, acquired from five distinct farms associated with Egypt's Animal Production Research Institute (APRI) in Kafr El-Sheikh province, notable findings emerged. There was a marked influence of calving age and parity order on the milk yields, with buffaloes aged 8-10 years exhibiting peak yields. A significant uptrend was observed in milk yield metrics from the initial to the seventh parity. Notably, reproductive durations, including days open, calving intervals, and dry periods, peaked during the first parity. Economic evaluations revealed that first parity buffaloes recorded the least production expenditures. In contrast, seventh lactation buffaloes were the most profitable. A noteworthy observation was that buffalo calving less than six years demonstrated reduced production costs. Net profit showed the peak within the age of less than 6 to 8 years before tapering off. Contrarily, calf gender remained inconsequential across the studied parameters. The study highlights the importance of integrating production, reproductive, and economic determinants in buffalo breeding optimization strategies.

Introduction

The buffalo stands out as a key dairy animal (Eldawy *et al*., 2021). Its significance lies in its abundance of desirable attributes. It serves as a notable source of both milk and meat known for its delectable taste and nutritional content. The milk from buffalo, notably richer in energy than cow milk, boasts high calcium content and is abundant in essential minerals like magnesium, potassium, and phosphorus. Apart from its high-fat content, buffalo showcases adaptability to less favorable environments and poor management practices. Its resilience against diseases, parasites, long lifespan, draught capability, and satisfactory growth rate further underscores its importance. Notably, buffaloes can efficiently process lower-quality feeds like straws and agricultural by-products into nutritive human food while contributing to soil enrichment via bio-fertilizers (ShafiK, 2017; Ranjitha *et al*., 2020; FAO, 2023). Nonetheless, challenges remain, such as their suboptimal reproductive performance, exhibited by extended calving intervals and prolonged reproductive maturity (Amin *et al*., 2021; Easa *et al*., 2022). Given the fertility concerns leading to higher culling rates, assessing these aspects becomes essential for optimized breeding and farm management strategies (Ansari-Lari *et al*., 2012; Gabr, 2015).

Milk production and calving intervals are vital determinants of the economic efficiency of a dairy herd. As such, dairy buffalo owners are committed to elevating both reproductive and production attributes of their livestock (Bashir *et al*., 2007; El-Tarabany, 2015). Enhancing buffalo yields is dependent on the careful selection of superior breeding stock. A key consideration in increasing milk productivity involves the examination of the lactation curve of a dairy animal, given that milk quality and market price are fundamentally linked (Boro *et al*., 2018).

It's essential to understand both physiological and environmental determinants that are crucial for animal's performance to optimize dairy buffalo productivity. While genetic makeup fundamentally controls physiological elements, environmental factors exert a significant and complex impact on buffalo performance (Zicarelli, 1997).

These environmental determinants comprise factors like the animal's age at calving (Kumar *et al*., 2017; Oz *et al*., 2022), the number of calvings (Bampidis *et al*., 2012; Yadav *et al*., 2013; Hassan *et al*., 2017), and the gender of the calf (Oliveira *et al*., 2017; Al-Fayad and Shareef, 2022)

The goal of this work was to assess buffalo productivity under the effect of different calving ages, parities, and calf gender, on productive, reproductive as well as the economic evaluation in order to maximize the profitability of buffalo farms.

Materials and methods

Animal management

This study utilized animals housed at the buffalo research station in Mahallet-Mousa, Kafr El-Sheikh, Egypt. Prior to the study initiation, ethical clearance (number BUFVTM06-08-23) was secured from the Animal Care and Welfare Committee at the Faculty of Veterinary Medicine, Benha University, Egypt. Data from 2112 buffalo records kept at five farms owned by APRI in the Egyptian province of Kafr-Elsheikh between 1994 and 2022 were processed. The animals were given a diet in alignment with APRI's nutritional guidelines (1997, unpublished data), ensuring their health and production needs. Milking occurred twice a day, and the buffaloes were sheltered in semi-covered spaces, with vaccinations administered as mandated by the General Authority for Veterinary Services. Natural

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breeding methods were adopted for reproduction. Selection criteria for the records considered the days in milk (ranging between 120 and 392) and a calving interval of 300 to 700 days. Only the completed calving and lactation records of ≥ 5 kg daily milk yield were included for evaluation.

Productive indices

The studied parameters were Days in milk (DIM), the days from the time of parturition to drying off, total milk yield (TMY) and daily milk yield (DMY), which was determined by dividing the total lactation milk production by the days in milk. This yield was then adjusted to a 270-day lactation period based on Oliveira *et al.* (2017) methodology.

Reproductive indices

The following parameters related to reproduction have been noted: days open (DO), known to be the time between calving and conception, calving interval (CI), defined as the duration recorded in days between two consecutive parturitions. Days dry (DD), referred to the number of days from drying off to the subsequent calving.

Economic Analysis

The economic evaluation considered various expenses including daily feed, milk price, veterinary supervision, medications, sanitation products, labor, and other miscellaneous expenses have been spent on other facilities such as water and electricity etc.). These were used to compute the feed, variable, and total costs per animal, alongside the milk revenue, total return, and net profit (Kopeček and Martínková, 2012), using the Egyptian pound (EGP) relying on prevailing prices in the market during the research period. Expenses linked to natural insemination were derived from the total cost of maintaining the male buffaloes and then distributed across lactating females in the farm. The total expenditures during the calving interval were summed to get the total costs, while milk revenue was derived by multiplying the total produced milk by its price. Total return is the sum of the profits from the sales of manure, milk, and calves. The net profit was computed by subtracting total expenses from total return.

Statistical Analysis

Data characteristics were subjected to analysis via the General Linear Model (GLM) incorporated in the SAS software package (SAS, 2001) (Version 8.2; SAS Institute Inc., Cary, NC, USA) as follows:

$Y_{ijkl} = \mu + Pa_i + AC_j + Cg_k + e_{ijkl}$

Where: Y_{ijkl} is the measured value (i.e., DIM, TMY, DMY, 270_DMY, DO, CI, DD, Feed expenses, variable expenses, Total expenses, Milk return, Total return, and Net profit), μ is the overall mean, Pa_i is the effect of ith parity; (where i= 1, 2, up to 9, whereas 1= 1st parity, 2= 2nd parity, 3=3rd parity, 4=4th parity, 5= 5th parity, 6= 6th parity, 7= 7th parity, 8= 8th parity, and 9= 9th and more parities), ACj is the effect of jth age at calving; (j= 1, 2, 3 and 4, whereas 1= <6 years, 2= 6-8 years, 3 = 8-10 years, and 4= >10 years), Cg_k: is the effect of kth calf gender; (k= 1, and 2, whereas 1= male, 2= female), and e_{ijkl} is the random error.

Results

Lactation metrics

Least squares means of the effects of age at calving, parity, and calf gender on lactation metrics are presented in Table 1. Regarding TMY, DMY, and 270-DMY, results showed a general trend of increasing milk production to reach its maximum production of 1857.68±34.06, 8.83±0.13, and 2389.08±33.43 Kg for TMY, DMY, and 270-DMY, respectively, at the calving age from 8-10 years then the milk production was slightly decreased with advanced age. Moreover, the milk production was significantly improved from first parity to reach its highest level in the seventh parity (1922.62±44.38, 9.24±0.16, and 2479.65±43.56 kg), for TMY, DMY, and 270-DMY, respectively, and then the milk production level was reduced after, with concurrent lactations. Furthermore, the milk yield showed slight increased levels in buffaloes with female calf; however, the effect of calf gender was non-significant.

Reproductive parameters

Least squares means the effects of age at calving, parity and calf gender on DO, CI, and DD are presented in Table 2. It was noticed that DO, CI, and DD were at their lowest values for buffaloes gave their calving at the

Table 1. Least squares means ±SE of age at calving, parity, and calf gender on milk production metrics.

Item	Level	N	DIM/days	TMY/kg	DMY/kg	270_DMY/kg
Age at Calving	>6 years	737	212.96±3.52	1745.45^{b}±40.91	8.30^{b}±0.15	2224.21^{b}±40.15
	6-8 years	497	213.29±2.69	1841.13^{a}±31.36	8.76^{a}±0.12	2349.79^{a}±30.77
	8-10 years	372	211.81±2.93	1857.68^{a}±34.06	8.83^{a}±0.13	2389.08^{a}±33.43
	<10 years	506	211.90±4.33	1826.24^{ab}±50.41	8.61^{ab}±0.19	2342.83^{ab}±49.48
Parity	1	144	219.73±4.97	1514.06^{c}±57.86	6.98^{d}±0.21	1883.03^{c}±56.78
	2	293	218.42±4.37	1731.63^{b}±50.90	7.99^{c}±0.19	2164.57^{b}±49.95
	3	312	215.34±3.82	1849.02^{a}±44.46	8.62^{b}±0.16	2341.21^{a}±43.63
	4	289	211.19±3.17	1841.43^{a}±36.88	8.68^{b}±0.14	2357.36^{a}±36.20
	5	241	209.26±3.05	1836.36^{ab}±35.46	8.78^{b}±0.13	2379.75^{a}±34.81
	6	211	210.95±3.25	1869.38^{a}±37.78	8.91^{ab}±0.14	2397.62^{a}±37.08
	7	163	209.86±3.81	1922.62^{a}±44.38	9.24^{a}±0.16	2479.65^{a}±43.56
	8	154	209.27±4.73	1900.62^{a}±55.01	9.22^{ab}±0.20	2472.98^{a}±53.99
	≥ 9	305	208.41±4.66	1893.49^{a}±54.24	9.21^{ab}±0.20	2462.15^{a}±53.23
Calf gender	Male	1119	212.96±1.26	1814.18±14.70	8.59±0.05	2318.63±14.43
	Female	991	212.02±1.33	1821.07±15.45	8.66±0.06	2334.33±15.16

SE: standard error of the mean. $^{a-c}$Means with different superscripts letters are significantly different (P<0.05).
DIM: days in milk; TMY: total milk yield; DMY: daily milk yield; 270_DMY: 270-day milk yield

age below 6 years old (63.94, 12.13, and 156.69 days, respectively). However, buffaloes between 8 and 10 years and > 10 years showed the highest values of DO, CI, and DD (94.46, 13.05 and 186.18 days respectively) and (98.05, 13.20 and 190.84 days respectively). Moreover, DO, CI, and DD exhibited the minimum results from 6th parity and thereafter. While, the first parity showed the longest periods.

Economic parameters

Least squares means for the influences of age at calving, parity, and calf gender on economic efficiency are presented in Table 3 and 4. The results revealed that feed, variable and total expenses were the lowest for buffaloes calving for the first time (34879.63, 36186.77 and 38330.41 EGP, respectively) compared to other parities. However, milk, total and net return recorded the lowest significant values in first parity (27250.37, 43515.37, and 5184.96 EGP, respectively), while the highest values of return parameters were estimated in buffalo cows from seventh lactation. It was also observed that buffaloes that calved at age of >6 years had significantly the lowest production expenses, milk return, and total return compared to those calving in the other ages. Furthermore, there was non-significant increase in net profit at the age range of > 6 years and 6-8 years (10273.79 and 10240.19 EGP, respectively), then declined later. Nevertheless, no significant differences were detected due to the calf sex for all studied parameters.

Discussion

Milk serves as the primary source of income in buffalo farming. Nonetheless, our study did not yield significant results when examining the impact of age on Days in Milk (DIM). In contrast, another investigation conducted by Koçak *et al.* (2019) identified a significant effect of age on

Table 2. Least squares means ±SE of age at calving, parity, and calf gender on reproductive parameters.

Item	Level	N	DO	CI	DD
Age at Calving	>6 years	737	63.94^{c}±4.54	12.13^{c}±0.15	156.69^{c}±4.70
	6-8 years	497	83.38^{b}±3.48	12.71^{b}±0.12	174.45^{b}±3.60
	8-10 years	372	94.46^{a}±3.78	13.05^{a}±0.13	186.18^{a}±3.91
	<10 years	506	98.05^{a}±5.59	13.20^{a}±0.19	190.84^{a}±5.79
Parity	1	144	123.97^{a}±6.41	13.97^{a}±0.22	206.57^{a}±6.64
	2	293	112.91^{b}±5.64	13.63^{b}±0.19	197.44^{ab}±5.84
	3	312	102.34^{c}±4.93	13.30^{c}±0.17	190.28^{b}±5.10
	4	289	84.64^{d}±4.09	12.75^{de}±0.14	177.76^{c}±4.23
	5	241	76.82^{de}±3.93	12.53^{de}±0.13	172.87^{cd}±4.07
	6	211	71.71^{e}±4.19	12.37^{e}±0.14	165.94^{cd}±4.34
	7	163	63.81^{e}±4.92	12.14^{e}±0.17	160.36^{d}±5.09
	8	154	65.79^{e}±6.10	12.15^{e}±0.20	161.24^{cd}±6.31
	≥ 9	305	62.64^{e}±6.01	12.11^{e}±0.20	160.93^{cd}±6.23
Calf gender	Male	1119	84.33±1.63	12.76±0.05	176.23±1.69
	Female	991	85.59±1.71	12.79±0.06	177.86±1.77

SE: standard error of the mean. a-e Means with different superscripts letters are significantly different (P<0.05).
DO: Days open; CI: Calving interval; DD: days dry.

Table 3. Least squares means ±SE of age at calving, parity, and calf gender on feed, variable, and total expenses.

Item	Level	N	Feed expenses	variable expenses	Total expenses
Age at Calving	>6 years	737	34109.20^{b}±496.66	35262.32^{b}±506.57	37407.45^{b}±506.63
	6-8 years	497	35815.46^{a}±380.71	37017.73^{a}±388.31	39162.99^{a}±388.35
	8-10 years	372	36748.23^{a}±413.55	37978.40^{a}±421.80	40126.97^{a}±421.85
	<10 years	506	37033.93^{a}±612.08	38276.96^{a}±624.29	40425.98^{a}±624.36
Parity	1	144	34879.63^{d}±702.49	36186.77^{c}±716.51	38330.41^{c}±716.59
	2	293	37255.49^{ab}±617.95	38534.19^{ab}±630.29	40681.99^{ab}±630.36
	3	312	37685.91^{a}±539.75	38936.78^{a}±550.53	41084.76^{a}±550.59
	4	289	36422.30^{bc}±447.82	37627.83^{bc}±456.75	39775.19^{bc}±456.81
	5	241	35830.00^{bcd}±430.59	37017.04^{bc}±439.18	39162.80^{bc}±439.23
	6	211	35626.42^{bcd}±458.75	36799.19^{c}±467.91	38945.40^{c}±467.96
	7	163	35354.48^{bcd}±538.88	36509.05^{c}±549.64	38657.23^{c}±549.70
	8	154	35253.89^{bcd}±667.89	36409.31^{c}±681.22	38557.35^{c}±681.30
	≥ 9	305	35032.24^{cd}±658.57	36184.53^{c}±671.72	38332.49^{c}±671.79
Calf gender	Male	1119	35899.14±178.53	37105.36±182.10	39253.43±182.12
	Female	991	35954.28±187.54	37162.35±191.29	39308.26±191.31

SE: standard error of the mean. $^{a-c}$ Means with different superscripts letters are significantly different (P<0.05).

Table 4. Least squares means ±SE of age at calving, parity, and calf gender on milk return, net return, and net profit.

Item	Level	N	Milk return	Total return	Net profit
Age at Calving	>6 years	737	31416.24^{b}±736.30	47681.24^{b}±736.30	10273.79±554.44
	6-8 years	497	33138.18^{a}±564.40	49403.18^{a}±564.40	10240.19±425.00
	8-10 years	372	33435.99^{a}±613.08	49700.99^{a}±613.08	9574.02±461.66
	<10 years	506	32869.16^{ab}±907.40	49134.16^{ab}±907.40	8708.18±683.29
Parity	1	144	27250.37^{c}±1041.43	43515.37^{c}±1041.43	5184.96^{f}±784.22
	2	293	31166.49^{b}±916.11	47431.49^{b}±916.11	6749.51^{e}±689.85
	3	312	33279.56^{a}±800.18	49544.56^{a}±800.18	8459.80^{d}±602.55
	4	289	33143.70^{a}±663.89	49408.70^{a}±663.89	9633.51^{cd}±499.92
	5	241	33051.60^{ab}±638.34	49316.60^{ab}±638.34	10153.80^{bc}±480.68
	6	211	33646.40^{a}±680.09	49911.40^{a}±680.09	10966.00^{abc}±512.12
	7	163	34604.86^{a}±798.89	50869.86^{a}±798.89	12212.63^{a}±601.58
	8	154	34209.69^{a}±990.15	50474.69^{a}±990.15	11917.34^{ab}±745.60
	≥ 9	305	34081.37^{a}±976.33	50346.37^{a}±976.33	12013.87^{ab}±735.19
Calf gender	Male	1119	32652.91±264.67	48917.91±264.67	9664.48±199.30
	Female	991	32776.88±278.03	49041.88±278.03	9733.62±209.36

SE: standard error of the mean. $^{a-c}$ Means with different superscripts letters are significantly different (P<0.05).

lactation length (P<0.001).

Our findings indicate a general trend of increasing milk production, reaching its peak between the ages of 8 to 10 years, with a subsequent slight decrease in milk production as age advances. Correspondingly, Koçak *et al.* (2019) reported a significant influence of calving age on milk yield, with the highest yield (1145.60 kg) observed in buffaloes aged 9 years. Bharti *et al.* (2015) concluded that udder morphological traits in Murrah Buffaloes varied as age advanced, while Khatri *et al.* (2017) noted that multiparous buffaloes had significantly larger udder volumes compared to primiparous ones. In contrast, Oliveira *et al.* (2017) found no substantial difference in either DMP or TMP among buffaloes based on parity order.

Our research suggests a significant increase in milk yield from the lowest yield in the 1st and 2nd parities to reach the peak yield in the 7th parity, followed by a slight decline in subsequent lactations. This trend aligns with findings reported by Yadav *et al.* (2013), who observed increased milk yield up to the 5th parity, followed by a decline. However, Bashir *et al.* (2015) reported that total milk yield (TMY) exhibited a dramatic increase in the first two parities, peaked in the third lactation, and then declined in later parities.

Additionally, Ranjitha *et al.* (2020) found that average daily milk yield increased from the 1st (7.00±0.39 kg) to the 6th (9.63±0.54 kg) parity. Similarly, Eldawy *et al.* (2021) reported a significant increase in total milk production from the first to the sixth parity, followed by a decrease in the seventh season. Furthermore, Al-Fayad and Shareef (2022) revealed a significant effect of birth sequence on daily milk yield, with buffaloes in the 4th parity and beyond outperforming those in the 1st parity. This difference may be attributed to factors such as body size, digestive system size, and udder tissue development with repeated births, as noted by Nyamushamba *et al.* (2014).

The increase in milk production with age is linked to the growth of the buffalo's body weight and mammary gland. The mammary gland development is influenced by various factors, including growth stage, sexual maturation, recurring pregnancies, and lactations, as reported by Baldwin and Miller (1991). Additionally, an increase in production with age corresponds to increased body weight, an expanded digestive tract, and mammary gland size. Thus, birth sequence emerges as a significant factor affecting milk production in cattle, including buffaloes, as explained by Almiah (2010).

Milk yield exhibited slight increases in buffaloes with female calves, though the effect of calf gender was not statistically significant. Similarly, Paranhos da Costa *et al.* (2000) did not observe a significant relationship between milk production and calf gender. In contrast, studies by Landete-Castillejos *et al.* (2005) and Oliveira *et al.* (2017) reported higher milk yields in cows with male calves. Additionally, Al-Fayad and Shareef (2022) noted a significant effect of newborn gender on DMY.

The current investigation revealed that DO, CI, and DD were at their lowest values for buffaloes calving at an age below 6 years old. This outcome may be attributed to the positive correlation between Age at First Calving (AFC) and CI; Buffaloes calving at a younger age tended to have shorter calving intervals, as indicated by Easa *et al.* (2022). Conversely, older buffaloes, aged over 10 years, displayed an increasing trend in DO, CI, and DD with advanced calving age. According to Eldawy *et al.* (2021), milk yield showed positive correlations with DO and CI, both of which increased with higher levels of TMY (P<0.05). DO represents the interval between calving and conception and is an important indicator of fertility in dairy animals, as noted by Eldawy *et al.* (2021). The calving interval, which represents the period between successive calving dates, can affect milk production and progeny production in buffalo cows if prolonged, as highlighted by Kumar *et al.* (2017).

The prolonged CI and DO, along with high milk production in buffaloes, may be attributed to metabolic and hormonal changes in dairy animals (Çolakoğlu *et al.*, 2019), leading to decreased concentrations of insulin-like growth factor-1 and reproductive disorders (Elsayed *et al.*, 2019). Negative energy balance (NEB) can affect endometrial immunity and ovarian functions, impacting both steroidogenesis and folliculogenesis, as discussed by Roche *et al.* (2000) and Vanholder *et al.* (2006). Highly productive buffaloes may suffer from hormonal imbalances that interfere with normal reproductive performance, resulting in prolonged CI and DO (Fathy *et al.*, 2023).

Our study revealed significant effects of parity, on DO, CI, and DD, with reductions observed in recurrent parities, reaching their lowest levels in advanced parities. Sosa *et al.* (2016) observed a higher incidence of anestrus in first-calving water buffaloes compared to those in the second and third parities, leading to extended calving to first estrus and conception intervals. Primiparous buffaloes exhibited prolonged CI, associated with longer estrous periods, higher DO, and conception rates, as indicated by Jakhar *et al.* (2017). Additionally, lower weights in early lactations could reduce the chances of pregnancy during the first insemination, as low energy demands are associated with ovarian activity and estrous expression, as suggested by Bastin *et al.* (2010). Thiruvenkadan *et al.* (2014) reported a negative correlation between parity order and DO in Murrah buffaloes. Additionally, they recorded the longest DP with the first parity buffalo-cows. However DP was significantly declined in later parities. Hassan *et al* (2017) recorded highly significant effect of parity on DO and CI, with the longest DO and CI were observed with Buffaloes in their first parity and then declined thereafter. Moreover, they observed that the DP was the longest of 266.30±18.31 days for the first calf buffalo-cows. Inconsistence to our results, Koçak *et al.* (2019) reported significant age-related impacts on calving interval (P<0.001). Similarly, the investigation of Eldawy *et al.* (2021) showed highly significant effects of parity number on DO and CI, while other reports indicated that parity had a limited effect on calving interval, as mentioned by Marai *et al.* (2001); Bhatti *et al.* (2007) and Mberato *et al.* (2016). However, Hussain *et al.* (2006) found that the effect of parity on DP was non-significant.

The conflicting results regarding age at calving and parity may be attributed to differences in age at first calving (AFC) for the buffaloes, leading to variations in calving age, as well as differences in calving seasons. Further investigation is needed to clarify these discrepancies.

Notably, this study revealed that calf gender had a non-significant

effect on DO, CI, and DD; however, they slightly increased in buffalo-cows with female calves.

Regarding economics, the variation in costs and profits among dairy buffalo farms can be largely attributed to parity (Hassan *et al*., 2017). The first lactation buffaloes and those with lower ages demonstrated lower feeding, variable, and total costs compared to other lactations. These findings align with previous research by Bashir *et al*. (2015), which noted that higher feed costs were typically associated with higher milk production. Moreover, buffaloes in the seventh and subsequent lactations exhibited the highest net profit, consistent with the conclusions of Bashir *et al*. (2015), who found that lifetime performance significantly influences the economic returns of dairy buffaloes. Reproductive and productive performances were not influenced by calf sex, resulting in unaffected economic parameters.

Our study indicated that when animals' age increased, the production costs also increased. Numerous studies have indicated a negative correlation between milk production and fertility (Pryce *et al*., 2004; Easa *et al*., 2022), leading to increased expenses related to semen, veterinary services, DO, services per conception, and CI. This relationship has been previously reported (Kadarmideen *et al*., 2003; Wall *et al*., 2003). Furthermore, low profitability caused mainly by decreased reproductive performance (Abulaiti *et al*., 2021).

Conclusion

The age of calving and parity are key factors in the production, reproductive performance, and economic aspects of dairy buffalo management. Research indicates that dairy buffaloes calving before the age of six and those in their seventh parity demonstrate improvements in milk production, reproductive outcomes, and economic indicators. Consequently, it is advisable to adjust buffalo breeding programs to commence calving at a younger age to sustain higher milk yields, enhance reproductive success, and optimize economic returns.

Conflict of interest

The authors declare that they have no competing interests.

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