Iranian Society of Animal Science
Journal of Livestock Science and Technologies
Shahid Bahonar University of Kerman
ISSN: 2322-3553 (Print) ISSN: 2322-374X (Online)

Paper type: Original Research

The effect of whole milk condensation by milk powder effervescent tablet on performance and health of neonatal Holstein dairy calves

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Received: 18 Jan 2025,
Received in revised form: 18 Mar 2025,
Accepted: 14 Apr 2025,
Published online: 15 Apr 2025,

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Abstract This study aimed to evaluate the effect of adding a milk powder effervescent tablet to whole milk on the performance and health of neonatal Holstein dairy calves. Individually housed calves (30 males and 30 females) were randomly assigned to one of three treatments from 0 to 56 d pre-weaning: 1) whole milk, 2) whole milk with 3% milk replacer, and 3) whole milk containing 3% milk powder effervescent tablet. From 56 to 70 d post-weaning, the calves were kept in the experiment until 70 d with the same starter feed. Calves enrolled in the study were fed 6 L/d of pasteurized whole milk in buckets twice daily at 0600 and 1600 from d 0 to 50, followed by morning feeding (2 L/d) from d 51 to 56 of age. Calves were weaned at d 56. Starter consumption, ambient temperature, and the fecal score were recorded daily. Calves were weighed every two weeks from birth until the end of the experiment. Rectal body temperature and frame development were measured on birth, weaning, and the final day of the experiment. The blood sample was taken at 56, and 70 d. Increasing the concentration of liquid feed by milk replacer powder and milk powder effervescent tablet improved body weight, average daily gain, heart girth, withers, and hip height without compromising any negative effects on average blood metabolites, rectal body temperature, average fecal score, and diarrhea duration. Also, increment of milk solids had no significant effects on starter intake during pre- and post-weaning. In conclusion, the condensation of whole milk with milk powder effervescent tablets up to 15.5% could be recommended as it facilitates a more practical concentration of milk for dairy calves. In summary, we strongly recommend using effervescent tablets formulated with milk powder to achieve a concentrated whole milk solution of 15.5%. This method not only enhances the practicality of milk concentration but also benefits the nutritional needs of dairy calves.

Keywords: milk solids increment, liquid feed, milk self-dissolving tablet, suckling calf

Introduction

The period from birth to weaning is crucial in a calf's life, as improved growth during the pre-weaning phase leads to a reduced age at first calving and enhanced performance during the first lactation (Meyer et al., 2006; Moallem et al., 2010). A meta-analysis found a synergistic relationship between pre-weaning dry matter intake (DMI) and first-lactation production (Gelsinger et al., 2016; Chester-Jones et al., 2017).

While the consumption of a starter is essential for rumen growth and development, research has indicated that during the neonatal period, a liquid feed is necessary to fulfill the nutritional requirements of young ruminants until they start ingesting sufficient quantities of a dry diet (Kertz et al., 2017;

Niwińska et al., 2022). Calves are born with underdeveloped rumen and initially rely on liquid feed for nutrients (Khan et al., 2016). Although restricted milk feeding has been a common practice to encourage early starter intake for earlier rumen development, this method cannot provide sufficient nutrients for the calf (Kiezebrink et al., 2015; Yunta et al., 2015). Studies demonstrated that higher milk consumption improved the calf growth welfare (Khan et al., 2011; Hammon et al., 2020), and health (Wu et al., 2021; Shen et al., 2023). Conversely, other research suggested that high consumption of milk delayed the ruminal growth, increased diarrhea (Hill et al., 2016), and reduced the pre-weaning starter intake that negatively impacted on the post-weaning DMI, average daily gain (ADG) and digestibility (Azevedo et al., 2023).

Concentrating the milk given to neonatal calves significantly increases the nutrients they receive from their liquid feed, leading to noticeable health and functional improvements. This approach lowers the risk of diarrhea (Norouzi et al., 2021) and enhances the overall well-being (Abbaslou et al., 2020). In terms of management, higher milk concentration helps prevent nutrient deficiencies (Azevedo et al., 2016) while boosting the nutrient intake and digestion (Glosson et al., 2015). Additionally, it supports better growth rates, skeletal development, and ADG (Lemraski et al., 2023; Júnior et al., 2024).

Many studies have shown that the dry matter (DM) of a calf's liquid feed can be increased up to 3% and this improves the growth of suckling calves. Adding this level of DM using milk replacer (MR) requires an accurate, fast, and easy method to simplify and shorten the preparation process, reduce the possibility of mixing errors, and ensure that the milk concentration is constant and optimal for feeding calves (Kasl et al., 2020). Effervescent tablets provide potential benefits for supplying concentrated milk to newborn calves. Their rising popularity stems from their simple administration and quick effectiveness (Vanhere et al., 2023). They contain acidic materials and carbonates or bicarbonates that react quickly in water, releasing carbon dioxide and improving solubility (Vanhere et al., 2023). This study investigated the effectiveness and practicality of whole milk concentration by milk powder effervescent tablets on the performance and health of neonatal Holstein dairy calves.

Materials and methods

Animals, housing, and treatments

This experiment was conducted at the Dairy Cattle Research Center of Ferdowsi University of Mashhad, Iran, from April to September 2023. The experimental procedures and animal manipulations were approved by the Animal Care and Use Committee of Ferdowsi University of Mashhad (FUM) outlined by the Iranian Council of Animal Care (Iranian Council of Animal Care, 1995). Furthermore, the Ethics Committee of FUM accepted and supervised all of the experimental processes (526/10/11/2021). Sixty Holstein dairy calves (30 males and 30 females), born between April and May 2023 were selected and separated from their dams at birth, weighed, and housed in separate pens (2.5 m × 2.2 m × 1.6 m; length × width × height). Calves were fed 3 L colostrum during the first 8 hours after birth (1.5 L at 1 h and 1.5 L at 8 h post birth) followed by feeding transition milk (10% of initial body weight; BW) thereafter. The calves enrolled in the study were fed 6 L/d of pasteurized whole milk (3.48 ± 0.01% fat, 3.15 ± 0.01% crude protein (CP), 5.33 ± 0.29% lactose, and 12.51 ± 0.09% total solids) in buckets twice daily at 0600 and 1600 from 0 to 50 d, followed by morning feeding (2 L/d) from 51 to 56 d of age. After weaning at 56 d, the calves were kept in the experiment until 70 d with the same starter feed to investigate their post-weaning performance.

The calves were randomly assigned to one of three treatments from 0 to 56 d pre-weaning and from 56 to 70 d post-weaning as follows: 1) whole milk (WM; 12.5% DM), 2) whole milk with 3% milk replacer (MR; 15.5% DM) and 3) whole milk containing 3% milk powder effervescent tablet (MR+; 15.5% DM). The amount of milk replacer to be added to the pasteurized whole milk (w/v) was adjusted to achieve the desired DM content for MR treatment. Commercial milk replacer (FOUDEH Imperial, Iran, Analytical constituents: 22% CP; 17% ether extract (EE); 8% ash; 0.1% crude fiber (CF); 0.9% calcium; 0.6% phosphorus) contained skim milk powder, whey powder, whey protein concentrate, refined vegetable fat, minerals, vitamins, and feed additives.

Milk powder effervescent tablets with a fixed composition (73% MR, 12% acidic materials, including 6.2% tartaric acid and 5.8% malic acid, and 15% bicarbonates, specifically sodium bicarbonate) were produced by a tablet special press machine. In MR+ treatment, one tablet was added to the milk (34 g/L) shortly before being fed to the calf. The milk powder effervescent tablet had a round shape with a diameter of 60 mm and a thickness of 10 mm. Upon dissolving the tablets in the liquid feed, the mixture had a pH of 6.5 ± 0.1. One hundred milliliters of the tank milk for each meal were analyzed daily using a Milko-Scan 605 analyzer (Foss Electric, Hillerod, Denmark) to adjust DM to 12.5%.

Sample collection and analysis

The mash starter and water were offered *ad libitum* throughout the experiment. The estimated amount of the starter was prepared once, and subsamples were taken for chemical analysis (Table 1). Analyses included DM (method 930.15; (AOAC, 2000), CP (Kjeldahl method 988.05; (AOAC, 2000), EE (alkaline treatment with Roese-Gottlieb method 932.06 for MR, diethyl ether extraction method 2003.05 for starters (AOAC, 2000), neutral detergent fiber (NDF) expressed inclusive of residual ash by the procedure without sodium sulfite and α-amylase (Van Soest et al., 1991), Acid detergent fiber

(ADF) was expressed inclusive of residual ash (Robertson and Soest, 1981), and ash (oven method 942.05; (AOAC, 2000). Temperature in the nursery was measured twice daily in the morning (0630) and afternoon (1630).

Table 1. Starter ingredients and nutrient composition

Items	%
Ingredients	
Alfalfa hay	10.0
Ground barley grain	25.2
Ground corn grain	13.5
Soybean meal	18.0
Wheat bran	10.8
Cotton seed meal	5.4
Flaxseed	8.1
Corn germ	3.6
Whole cotton seed	3.6
Salt	0.2
Dicalcium phosphate	0.2
Mineral and vitamin premix[1]	1.4
Nutrients composition[2]	
Dry matter	90.4
Metabolizable energy (Mcal/kg)[3]	2.64
Starch[3]	26.7
Crud protein	20.7
Ether extract	6.2
Neutral detergent fiber	25.8
Acid detergent fiber	14.1
Non-fibrous carbohydrate	42.3
Ash	5.6

[1]The premix contained: vitamin A 500000 IU/kg, vitamin D3 60000 IU/kg, vitamin E 3000 IU/kg, vitamin K 100 IU/kg, vitamin B_1 350 IU/kg, vitamin B_2 325 IU/kg, vitamin B_3 1000 IU/kg, vitamin B_5 1500 IU/kg, vitamin B_6 325 IU/kg, vitamin B_9 25 IU/kg, vitamin B_{12} 4 IU/kg, vitamin Biotin 10 IU/kg, vitamin Choline 50000 IU/kg, vitamin C 30000 IU/kg, Ca 80000 mg/kg, P 40000 mg/kg, Mg 80000 mg/kg, Na 120000 mg/kg, Fe 5000 mg/kg, Mn 2000 mg/kg, Zn 2000 mg/kg, Cu 500 mg/kg, I 20 mg/kg, Se 15 mg/kg, Co 10 mg/kg, Anti-Oxidant 1000 mg/kg and Carrier up to 1000 g.
[2]DM basis unless otherwise indicated.
[3]ME and starch calculated using NASEM (NASEM, 2021) equations.

Body weight, body frame development, and starter intake were monitored between 0 and 70 d of age. The average starter intake (ASI) was calculated by subtracting refusals from the feed provided and further adjusted for DM content to determine DMI from the starter feed. Calves were weighed every two weeks from birth until the end of the experiment. Body measurements including the heart girth (circumference behind the shoulder) body length (distance between the point of the shoulder and rump), withers height (distance from the base of the front feet to withers), hip height (distance from the base of the rear feet to hook bones), and hip width (distance between the points of hook bones) were recorded at birth, weaning, and on the final day of the experiment (Fouladgar et al., 2016).

The health status and fecal scores were monitored daily. Calves that required medication were treated per veterinary recommendation. A 5-point scale of 1=normal, 2=soft to loose, 3=loose to watery, 4=watery, mucous, and 5=watery, mucous, and bloody (Heinrichs et al., 2003) was used for scoring feces. Fecal scores of 4 and 5 were considered to indicate diarrhea. Rectal temperature (RBT) was measured at 0, 56, and 70 d. Jugular blood was sampled via venipuncture at 56, and 70 d, 4 h after the morning liquid feeding. Blood was collected into evacuated tubes and maintained until coagulated and then centrifuged for 10 min at 3000 rpm. The serum was obtained and frozen at –20 °C. Serum metabolites were analyzed by commercial kits (Pars Azmoon Kit; Karaj, Iran) using an automated analyzer (Vital Scientific N.V., Netherlands).

Statistical analysis

Before analysis, the data were screened for normality using the UNIVARIATE procedure (SAS, 2004). Data analysis was performed for a randomized block design using the following statistical model:

$$Y_{ijkl} = \mu + C_i + S_j + M_k + A_l + (M_k \times A_l) + e_{ijkl}$$

Where, Y_{ijkl} is the dependent variable; μ is the overall population mean; C_i is the random effect of the calf; S_j is the fixed effect of the block (sex); M_k is the fixed effect of milk DM; A_l is the fixed effect of the age; $(M_k \times A_l)$ is the interaction between milk DM and age; and e_{ijkl} is the random residual error term (assumed to be random and independently distributed). The data were analyzed using the repeated measures MIXED procedure (SAS, 2004).

Results

Performance

The effect of increasing DM of milk in treatments on ADG (g/d), ASI (g/d), and BW (kg/d) are shown in Figures 1-3. The ADG across different DM in milk showed a significant difference between the MR and MR+ treatments compared to the WM treatment. However, no significant difference was observed between MR and MR+ treatments, although calves in the MR treatment exhibited a higher ADG during both the pre-weaning and post-weaning periods (Figure 1). From 28 d onwards, there was a significant difference in BW amongst all treatments. Calves on treatments MR, MR+, and WM recorded the highest BW during the pre- and post-weaning periods, respectively (Figure 3).

Analysis of the ADG revealed significant differences ($P<0.05$) in growth performance across milk dry matter (DM) treatments (Figure 1). Calves receiving milk replacer treatments (MR and MR+) demonstrated superior ADG compared to whole milk (WM)-fed calves throughout the trial period. While no statistically significant difference ($P>0.05$) was observed between MR and MR+ groups, the MR treatment consistently showed numerically higher ADG values during both pre-weaning (+5.2%) and post-weaning (+3.8%) phases.

During the pre-weaning period, the ASI did not differ significantly among the treatments; however, calves in the MR treatment exhibited the highest feed consumption, while calves in the WM treatment showed the lowest. After weaning, ASI was notably higher in the MR treatment. Although there was no significant difference in feed consumption between the MR and MR+ treatments post-weaning, both groups consumed significantly more feed compared to the WM treatment (Figure 2).

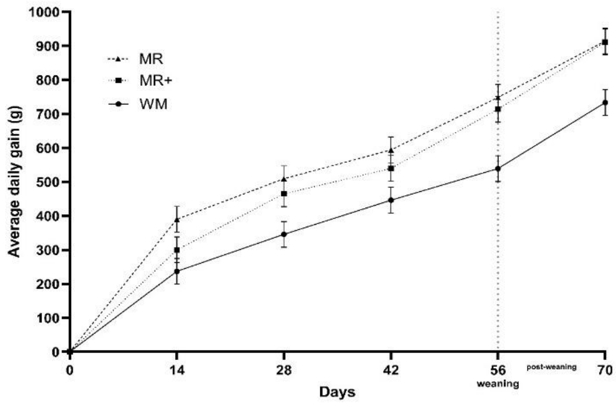

Figure 1. Effect of milk dry matter enhancement on average daily gain (g/d) in neonatal calves.
WM = whole milk; MR = milk replacer; MR+ = milk-effervescent tablet.

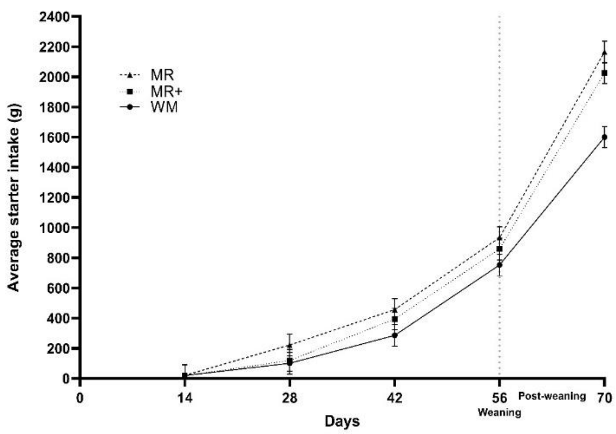

Figure 2. Effect of milk dry matter enhancement on average starter intake (g/d) in neonatal calves.
WM = whole milk; MR = milk replacer; MR+ = milk-effervescent tablet.

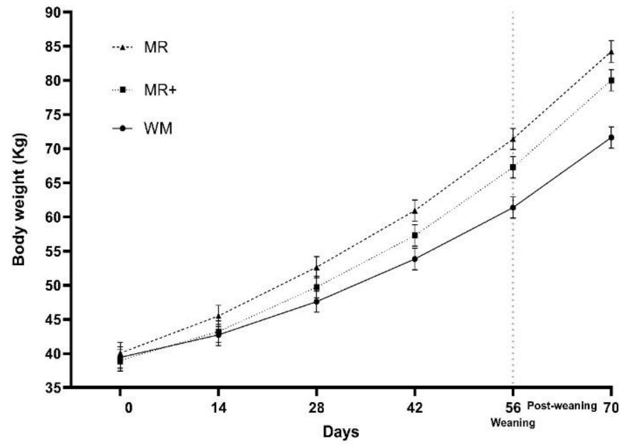

Figure 3. Effect of milk dry matter enhancement on body weight (kg/d) in neonatal calves.
WM = whole milk; MR = milk replacer; MR+ = milk-effervescent tablet.

Body development

The body frame development of calves during pre- and post-weaning periods is illustrated in Table 2. While skeletal parameters were generally similar across all treatments, significant differences were observed in the heart girth, withers height, and hip height among the treatments. At both weaning and 70 days of age, these three measurements were significantly greater in calves receiving MR and MR+ treatments compared to those receiving WM. Although the MR group exhibited higher values than the MR+ group, the differences between MR and MR+ were not statistically significant.

Table 2. The effect of enhancing milk dry matter on the body frame, diarrhea days and rectal temperature measurements in neonatal calves

		Treatment[1]			SEM	P-value[2]				
Measurement	**Period**	**WM**	**MR**	**MR+**		**T**	**G**	**P**	**T*P**	**T*G*P**
Heart girth (cm)	Pre-weaning	87.6	92.2	91.5	0.97	< 0.01	0.04	< 0.01	0.11	0.76
	Post-weaning	92.8	96.5	95.3						
Withers height (cm)	Pre-weaning	82.7	93.1	90.9	0.96	< 0.01	0.21	< 0.01	< 0.01	0.04
	Post-weaning	91.9	96.8	96						
Hip height (cm)	Pre-weaning	84.8	95.4	93.8	0.99	< 0.01	0.21	< 0.01	< 0.01	0.05
	Post-weaning	95.2	100.0	99.8						
Hip width (cm)	Pre-weaning	15.9	15.8	15.7	0.33	0.61	0.27	< 0.01	0.30	0.08
	Post-weaning	17.2	16.8	16.3						
Body length (cm)	Pre-weaning	47.8	48.6	48.6	0.72	0.48	0.09	< 0.01	0.25	0.02
	Post-weaning	50.5	52.1	52.3						
RBT[3] (˚C)	Pre-weaning	38.8	38.9	38.9	0.07	0.94	0.20	< 0.01	0.02	0.19
	Post-weaning	39.1	38.9	38.9						
Diarrhea day[4]	Pre-weaning	1.9	1.3	1.3	0.38	0.41	0.40	< 0.01	0.67	0.84
AFS[5]	Pre-weaning	2.18	2.01	2.05	0.19	0.36	0.18	< 0.01	0.53	0.27

[1] WM=whole milk; MR=milk replacer; MR+=milk-effervescent tablet.
[2] T=treatment; G=gender; P=Time.
[3] RBT=Rectal body temperature.
[4] Days with fecal score of 4 and 5.
[5] AFS=Average fecal score.

Health

Health indicators such as average RBT, average fecal score, diarrhea duration (Table 2) and blood metabolites (Table 3) were not affected by the treatments.

Table 3. The effect of enhancing milk dry matter on blood metabolites in neonatal calves

Measurement[1]	Period	Treatment[2]			SEM	P-value[3]				
		WM	MR	MR+		T	G	P	T*P	T*G*P
PVC (%)	Pre-weaning	24.3	27.9	25.7	1.10	0.11	0.81	0.46	0.74	0.94
	Post-weaning	25.6	27.9	25.8						
WBC (*10^3/ul)	Pre-weaning	8.73	6.47	8.02	0.78	0.09	0.69	0.28	0.67	0.22
	Post-weaning	8.65	7.93	9.07						
RBC (*10^6/ul)	Pre-weaning	8.05	9.00	8.71	0.36	0.18	0.86	0.53	0.68	0.63
	Post-weaning	8.14	8.93	8.98						
HCT (%)	Pre-weaning	24.2	27.9	25.7	1.11	0.12	0.74	0.48	0.58	0.97
	Post-weaning	25.7	27.7	25.9						
RDW (%)	Pre-weaning	16.0	16.8	16.3	0.55	0.50	0.27	0.50	0.23	0.99
	Post-weaning	17.0	16.8	17.1						
Fibrinogen (mg/dl)	Pre-weaning	466.7	366.7	333.3	56.9	0.19	0.32	0.13	0.89	0.64
	Post-weaning	516.7	433.3	433.3						
Total protein (g/dL)	Pre-weaning	5.91	6.12	6.08	0.12	0.43	0.09	0.24	0.67	0.19
	Post-weaning	6.08	6.25	6.08						

[1]PVC=packed cell volume; WBC=white blood cell count; RBC=red blood cell count; HCT=hematocrit test; RDW=red blood cell distribution width.
[2] WM=whole milk; MR=milk replacer; MR+=milk-effervescent tablet.
[3]T=treatment; G=gender; P=Time.

Discussion

Calves that consumed more solids through liquid feed (MR and MR+ treatments) had greater ADG, growth, and final BW during both the pre- and post-weaning periods. Similar to this study, Norouzi et al. (2021) and Lemraski et al. (2023) reported that increasing the liquid feed concentration for neonatal calves during the pre-weaning period resulted in higher BW and ADG. In addition to improvements in BW, calves that were fed with concentrated whole milk recorded increased heart girth and greater heights at the withers and hips throughout the experiment. Lemraski et al. (2023) also reported that the concentration of liquid feed solids led to higher heart girth, as well as increased withers and hip heights during the pre-weaning period. Additionally, Azevedo et al. (2016) noted that an increase in liquid feed solids resulted in an increase in heart girth and wither height during the pre-weaning period.

Our findings are in line with the previous research indicating that increasing the concentration of liquid feed did not impact on the starter consumption (Azevedo et al., 2016; Norouzi et al., 2021; Lemraski et al., 2023). However, after weaning and throughout the remainder of the experiment, we observed increased starter consumption in treatments with higher milk concentrations. This likely resulted from easier transitions from liquid to solid feed and improved ruminal development in the condensed milk treatments, which enhanced the calves' ability to consume starter feed.

Maintaining a consistent milk composition and stable liquid feed for calves is crucial (James and Scott, 2006; 2007; Hill et al., 2008) and to ensure this, the milk effervescent tablet was used in this study, which eliminates human error and prevents day-to-day variations in concentration by creating a uniform liquid feed. The use of milk powder effervescent tablets (MR+) led to better growth and performance parameters when compared to WM. However, their productivity was lower than that of MR, although the difference was not significant.

The milk powder effervescent tablet contains MR, sodium bicarbonate, tartaric acid, and malic acid. When the tablet is added to milk, these ingredients react to create sodium salts such as sodium tartrate and sodium malate, along with water and carbon dioxide. The MR also dissolves in the milk, increasing its concentration. Research on sodium supplements for neonatal calves shows little direct evidence regarding the effects of sodium malate and sodium tartrate. Studies have indicated that sodium chloride (NaCl) and sodium bicarbonate ($NaHCO_3$) can improve feed intake and growth when administered at approximately 20 grams of sodium per kilogram of DM (Kellaway et al., 1977). Furthermore, sodium citrate and sodium tartrate could influence calcium interaction with pectins, potentially affecting nutrient absorption and the digestibility of milk or MR by altering the gel properties in feed (Marudova and Jilov, 2003). Research suggests that sodium malate may have beneficial effects on metabolic indicators in neonatal calves, particularly in lowering serum L-lactate and creatinine levels (Hernández et al., 2011). Although these sodium compounds may influence digestion and nutrient absorption, further research is necessary to validate their effects on calf nutrition and growth. This study did not show any changes in health indicators; therefore, future research should investigate digestive functions and the effects of liquid feed concentration alongside milk powder effervescent tablets on the health and performance of neonatal calves.

Conclusions

Similar to a previous study conducted during autumn and winter, it was confirmed that also during spring and summer increasing the concentration of liquid feed to 15.5% DM enhanced the growth and performance of neonatal calves without impacting on their starter consumption or health. This adjustment also eased the transition from liquid to solid feed for calves on concentrated treatments and improved their starter consumption and growth after weaning. Effervescing the MR facilitated a more practical concentration of milk; however, it caused a non-significant reduction in growth and performance and therefore requires more research before adoption on commercial farms.

Acknowledgment

We want to thank the staff of the Dairy Research Center of the Ferdowsi University of Mashhad.

Statement of ethics

All the experimental procedures and animal manipulations were approved by the Animal Care and Use Committee of Ferdowsi University of Mashhad (Approval No: 526/10/11/2021).

Conflict of interests

No potential conflict of interest was reported by the authors.

Funding

The current study was supported by a grant from the Ferdowsi University of Mashhad, Iran.

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