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Short communication: Effects of Protoxin probiotic and weaning age on the performance, rumen and blood parameters in Kordi lambs

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Abstract This study evaluated the effects of probiotic supplementation (Protoxin) and weaning age on feed intake (FI), average daily gain, and selected ruminal and blood parameters in Kordi lambs, with the aim of identifying the most appropriate probiotic regimen and weaning age. Sixty newborn male Kordi lambs (initial body weight (BW) 4.4 ± 0.53 kg) were allocated to six treatments (n=10 lambs per treatment) for 90 d using a 2×3 factorial experiment in a completely randomized design. Lambs were housed in individual experimental pens with their dams and had access to creep feed. Treatments were as follows: (1) no probiotic, weaning at 45 d; (2) no probiotic, weaning at 67 d; (3) no probiotic, weaning at 90 d; (4) 0.5 g Protoxin/d, weaning at 45 d; (5) 0.5 g Protoxin/d, weaning at 67 d; and (6) 0.5 g Protoxin/d, weaning at 90 d. Probiotic supplementation began on d 1 of age, and starter feed was offered from the second week. Protoxin was dissolved in 10 mL of lukewarm water and administered orally by syringe once daily before morning feeding. Overall, Protoxin supplementation increased creep FI and BW gain, resulting in younger age at weaning. Protoxin contributed to improved growth performance of lambs by decreasing pH, NH3-N, and acetic acid concentrations while increasing propionic acid, and butyric acid concentrations in the rumen. Also, probiotic supplementation reduced blood glucose, BUN, interleukin-1 and interleukin-6 concentrations and improved blood protein profiles (albumin, globulin, and total protein), suggesting enhanced immune status. Although later weaning with Protoxin supplementation was able to further improve BW gain, feed conversion ratio (FCR) was not different among treatments receiving the probiotic. In contrast, later weaning increased the levels of proinflammatory cytokines, reduced blood glucose and total protein concentrations and increased rumen NH3-N. Based on the present findings, weaning at 45 d with 0.5 g Protoxin daily might be recommended for Kordi lambs to optimize performance and metabolic status.

Keywords: blood urea nitrogen, creep feeding, feed intake, gain, ammonia

Introduction

The economic viability of sheep production relies on efficient lambs rearing for replacement and fattening, with about 25% of ewes are culled annually (Chai et al., 2015). Key objectives include transitioning of suckling lambs to functional ruminants with minimal costs and losses, while maintaining health and growth. Optimal early-life nutrition and management are essential to stimulate rumen development, encompassing anatomical changes (increase in rumen mass and growth of the rumen papillae), functional achievement (fermentation capacity and enzyme activity) as well as microbial colonization (Liu et al., 2022). Probiotics are beneficial microbial supplements that by reducing pathogenic bacteria, improving dry matter (DM) intake and feed conversion ratio (FCR), improving nutrient utilization, stimulating immune cells and promoting overall growth and health performance, serving as alternatives to antibiotics (Nalla et al., 2022). Common probiotics include *Bifidobacterium*, *Lactobacillus* and yeast species, used to balance the intestinal microflora, prevent diseases, improve inflammation and digestion, and promote growth (Mao et al., 2023). Modulating gut microbiota could be a potential health strategy. Protoxin, a multi-strain probiotic, was studied in suckling lambs, at different doses based on the bacterial composition and number of viable bacteria in the product. Abdalla et al. (2020) showed that Protoxin improved rumen fermentation and papillary histomorphology in Najdi newborn lambs. Protoxin (3, 6, and 9×10^9 CFU/g) in milk replacer, enhanced digestive tract development and rumen parameters in suckling Zel lambs, leading to increased ruminal VFA, better morphological traits (Chashnidel et al., 2019), improved nutrients digestibility, elevated blood immune index (especially immunoglobulin G) and higher final weight with 9 grams in milk replacer (Chashnidel et al., 2018). However, a 0.2 g/lamb dose of Protoxin in Lori Bakhtiyari lambs showed no significant effects (Doralibeni et al., 2021), highlighting the need for more research on optimal probiotic in suckling lambs different breeds.

Early dry feed consumption is vital for rumen development and microbiota establishment, positively influencing adult ruminants' productivity and health (Liu et al., 2022). Also, it is essential to obtain optimum weaning age to minimize weaning stress and guarantee healthy growth of lambs after weaning (Chai et al., 2015). Optimal weaning age varies due to management, nutrition, and genotype differences, with inconsistent evidence affecting post-weaning health. Kordi sheep are an important native breed in Iran, but their optimal weaning age is not well-defined. This study hypothesized that appropriate weaning age combined with Protoxin supplementation would reduce the weaning stress and enhance growth.

Materials and methods

Experimental design, animal and diets

The experiment was conducted at the Kordi Sheep Breeding Center, located in Hosseinabad village, Bojnourd, North Khorasan province, Iran (37°28′20.03″ N, 57°19′44.51″ E), with ethical approval from the Sari Agricultural Sciences and Natural Resources University. Sixty newborn Kordi male lambs, after colostrum intake, with an average initial body weight (BW) of 4.40±0.53 kg, were randomly assigned to six treatments. All lambs were maintained with their dams under identical management conditions. In addition to unrestricted suckling, lambs had *ad libitum* access to concentrate mixture, alfalfa hay as roughage, and fresh water. The experimental treatments included: 1) no probiotic, weaned at 45 d of age; 2) no probiotic, weaned at 67 d of age; 3) no probiotic, weaned at 90 d of age; 4) Protoxin (0.5 g/lamb/d), weaned at 45 d of age; 5) Protoxin (0.5 g/lamb/d), weaned at 67 d of age; and 6) Protoxin (0.5 g/lamb/d), weaned at 90 d of age. Protoxin was suspended in water and administered orally before suckling (or the morning feeding) at a dose of 0.5 g in 10 mL of lukewarm per lamb per day, using a sterile syringe to ensure that each lamb received exactly the specified dose. After weaning, lambs were managed under a fattening program and monitored until 90 d of age. Diets were formulated to meet energy requirements according to NRC (2007) and consisted of concentrate and alfalfa hay at a concentrate-to-roughage ratio of 95:5 (Table 1). Protoxin (Probiotics International Ltd., England), a natural product consisted of nine beneficial microorganisms for the digestive system of sheep and lambs, including four *Lactobacillus* strains, one *Bifidobacterium* strain, one *Enterococcus* strain, one *Streptococcus* strain, and two fungal/yeast strains.

Table 1. Ingredients and chemical composition of the starter diet (g/kg DM, unless otherwise stated)

Ingredients	**Content**
Alfalfa hay, ground	50
Ground corn grains	335
Ground barley grains	270
Soybean meal	200
Cottonseed meal	53
Sugar beet molasses	20
Wheat bran	40
Vegetable oil	10
Premix[1]	5
Salt	2
Sodium bicarbonate	5
Calcium carbonate	10
Chemical composition	
Metabolizable energy (Mcal/kg DM)	2.3
Net energy of maintenance (Mcal/kg DM)	1.98
Net energy of growth (Mcal/kg DM)	1.65
Crude protein	180
Ca	9.5
P	4.8
Na	1.8

[1] Vitamin–mineral premix contained per kg: vitamin A 250,000 IU; vitamin D3 500,000 IU; vitamin E 1000 IU; Mn 1250 mg; Zn 2500 mg; Cu 375 mg; Se 25 mg; Ca 140000 mg; P 2500 mg; Co 20 mg; I 25 mg; Mg 25000 mg; Na 25000 mg as NaCl; Na 25000 mg as $NaHCO_3$ and 1000 mg antioxidant.

Growth performance

Individual BWs were recorded on days 1, 10, 22, 45, 67, and 90. To ensure consistency, lambs were weighed in the morning following a 12-h fast from both feed and water throughout the pre- and post-weaning periods. Feed intake was determined daily by recording the amounts of feed offered and refused, which allowed for the calculation of daily creep feed intake (FI). Furthermore, the average daily gain (ADG; g/lamb/d) was calculated as the difference between the final and initial BW divided by the total number of days on feed.

Rumen parameters

Ruminal fluid samples were collected on day 90 of the experiment using an orogastric tube at 1 h before morning feeding. The ruminal fluid was filtered through four layers of surgical gauze, and pH, ammonia nitrogen (NH_3-N), and volatile fatty acid (VFA) concentrations were determined. Ruminal pH was measured immediately after collection using a pH meter (Jenway, Model 350, UK). Ruminal NH_3-N concentration was determined using the Kjeldahl distillation method based on distillation with potassium hydroxide (KOH 2N) and collection of ammonia in boric acid (dos Santos et al., 2026).

For VFA analysis, 1 mL of the strained rumen fluid was mixed with 0.25 mL of an acid solution containing 200 mL/L of orthophosphoric acid and 20 mM 2-ethyl-butyric acid and frozen at -20ºC. Extraction of volatile fatty acids from rumen fluid resulted in two phases after centrifugation at 5000 ×g for 10 min. The lower phase was injected into the GC device for analysis. The composition of VFAs in the rumen fluid (butyric, propionic and acetic) was also calculated according to the method of Ottenstein and Bartley (1971) using a gas chromatography device (GC-FID 2014 Shimadzu Corporation).

Blood sampling and analysis

Blood samples (10 mL) were collected from the jugular vein of lambs on days 45, 67, and 90 (at their respective weaning age) pre-morning feeding. Samples were immediately placed on ice, centrifuged at 3000 × g for 10 min at 4°C, and the serum stored at –20°C. Serum glucose, total protein (TP), albumin, globulin, and blood urea nitrogen (BUN) were measured using diagnostic kits. Total protein and albumin concentrations were determined according to the methods described by Thomas (1988) and Doumas et al. (1971), respectively. Serum globulin concentration was calculated as the difference between TP and albumin (Siza et al., 2025). Urea was determined using the method of Marsh et al. (1965), and glucose was measured as described by Trinder (1969). Additionally, serum interleukin-1 (IL-1) and interleukin-6 (IL-6) concentrations were determined via ELISA using commercial kits (Eastbiopharm, Hangzhou Eastbiopharm Co., Ltd., China) following the manufacturer's instructions.

Statistical analysis

The experiment was conducted as a 2 × 3 factorial arrangement in a completely randomized design (CRD) using 60 suckling Kordi lambs (n=10). Factors studied included probiotic supplementation (0 and 0.5 g/lamb/d) and weaning age (45, 67, and 90 d). Data were analyzed using the GLM procedure of SAS (Version 9.1), incorporating the fixed effects and interactions with significance set at P≤0.05. Mean comparison was evaluated by the Duncan's multiple range test. The mathematical model used for the analysis was as follows:

$$Y_{ijk}=\mu + T_j + S_j + (TS)_{ij} + e_{ijk}$$

where, Y_{ijk}: value of each observation, T_i: probiotic supplement effect, S_j: weaning age effect, $(TS)_{ij}$: interaction effect of supplement level and weaning age, e_{ijk}: experimental error effect and μ: overall mean.

Results

Creep feed intake, average daily gain and feed conversion ratio

The effects of experimental treatments on performance in Table 2 shows that during the 23- to 45-day age interval, probiotic supplementation significantly increased creep FI; however, weaning age did not significantly affect creep FI (P>0.05). Over the entire study period (10–90 d), creep FI was significantly increased by probiotic supplementation (P<0.05). Lambs supplemented with probiotics and weaned at 45 days exhibited higher creep FI than other groups. No significant interaction was observed between probiotic and weaning age regarding FI.

Average daily gain did not differ significantly pre-weaning (up to 45 d; P>0.05), but from 45–67 d interval, lambs weaned at 45 d showed lower ADG compared to later weaning ages (P<0.001). Protoxin significantly increased ADG during this period (P<0.001). For the 68-90 d period, ADG was lower in lambs weaned at 67 d (P<0.01), whereas probiotic supplementation consistently improved growth performance (P<0.01). A significant interaction was observed in this period, with the highest ADG in lambs weaned at 90 days with probiotics. Overall, probiotic supplementation significantly enhanced ADG, particularly in lambs weaned at 90 days.

Feed conversion ratio was not significantly different among treatments during the pre-weaning period (up to 45 d; P>0.05). However, during the 45-67 d, lambs that received probiotics showed a lower FCR (P<0.001). During the same period, FCR was higher in lambs weaned at 45 d (P<0.001). During the 68-90 d period, a significant interaction was observed between weaning age and probiotic supplementation, where lambs weaned at 90 d and receiving probiotic supplementation had the lowest FCR, while lambs that weaned at 45 d without probiotic showed the highest FCR. The overall FCR (10-90 d) was significantly reduced by probiotic supplementation and was lowest in the group weaned at 90 d and supplemented with the probiotic (P<0.001).

Rumen parameters

The effects of experimental treatments on ruminal fermentation parameters in Table 3 shows that Protoxin supplementation significantly reduced ruminal NH_3-N in lambs (P<0.05), while increasing the weaning age significantly elevated ruminal NH_3-N concentrations (P<0.05). A significant interaction was observed, with the lowest NH_3-N concentrations in the probiotic-supplemented group weaned at 45 d. Ruminal pH values, measured at 1 h before morning feeding, were similar across all treatments (P>0.05).

Table 2. Effect of weaning age and probiotic supplementation on average daily gain and creep feed intake of lambs (g/lamb/d)

	Experimental treatments									
Probiotic (g)	Pro 0			Pro 0.5			SEM[1]	*P*-value		
Weaning age (day)	45	67	90	45	67	90		probiotic	weaning age	Age × Pro
Creep feed intake (g/lamb/d)										
10-22	72.00	64.66	66.66	70.97	69.83	68.58	1.242	0.4323	0.3382	0.6081
23-45	363.68^{b}	363.61^{b}	363.57^{b}	385.39^{a}	383.17^{a}	383.15^{a}	0.325	<.0001	0.2833	0.3393
46-67	555.55	546.71	546.90	550.81	547.67	547.57	1.413	0.7196	0.1804	0.6606
68-90	715.52	716.93	713.19	717.17	717.39	712.61	0.737	0.7344	0.0801	0.8285
10-90	478.60^{d}	477.25^{cd}	476.70^{c}	485.99^{a}	483.85^{b}	482.46^{b}	0.231	<.0001	0.0013	0.3728
ADG[2] (g/lamb/d)										
10-22	135.00	138.00	138.67	140.00	140.33	143.00	2.621	0.0942	0.4683	0.8706
23-45	145.37	148.22	144.75	155.03	154.03	150.07	2.257	0.1506	0.7867	0.9121
46-67	147.70^{d}	163.40^{c}	164.45^{c}	181.74^{b}	200.00^{a}	206.03^{a}	1.303	<.0001	<.0001	0.5065
68-90	171.69^{c}	196.34^{b}	211.04^{ab}	216.70^{ab}	202.73^{b}	228.03^{a}	2.540	0.0007	0.0038	0.0244
10-90	154.92^{d}	169.32^{c}	173.41^{c}	184.49^{b}	185.59^{b}	194.71^{a}	1.173	<.0001	0.0012	0.0152
FCR[3]										
10-22	0.53	0.47	0.48	0.44	0.48	0.48	0.021	0.1327	0.7754	0.0872
23-45	2.50	2.46	2.51	2.49	2.49	2.58	0.095	0.7240	0.7218	0.9026
46-67	3.76^{a}	3.35^{b}	3.33^{b}	3.03^{c}	2.74^{d}	2.66^{d}	0.068	<.0001	0.0001	0.6775
68-90	4.17^{a}	3.65^{b}	3.38^{bc}	3.31^{bc}	3.55^{b}	3.13^{c}	0.114	0.0009	0.0031	0.0141
10-90	3.19^{a}	2.95^{b}	2.89^{b}	2.72^{c}	2.74^{c}	2.65^{c}	0.035	<.0001	0.0008	0.0059

[a,b] Within row, mean values with common letter(s) are not different (P>0.05).
[1]SEM, Standard error of the mean; [2]ADG, Average daily gain, [3]FCR, Feed conversion ratio

Table 3. Effect of weaning age and probiotic supplementation on rumen parameters in lambs

	Experimental treatments									
Probiotic (g)	Pro 0			Pro 0.5			SEM[1]	*P*-value		
Weaning age (day)	45	67	90	45	67	90		Probiotic	weaning age	Age × Pro
NH3-N (%)										
1 h before feeding	3.82^{cd}	3.91^{bc}	4.14^{a}	3.57^{e}	3.76^{d}	3.97^{b}	0.014	0.0209	0.0001	0.0001
pH										
1 h before feeding	7.11	7.03	6.96	7.12	7.01	6.73	0.089	0/6300	0/0697	0/0749
Volatile fatty acids (mmol/L)										
Acetic acid	19.88^{d}	35.37^{b}	41.01^{a}	15.33^{e}	22.15^{d}	24.67^{c}	0.325	0.0001	0.0001	0.0001
Propionic acid	24.15^{a}	17.98^{c}	24.15^{a}	24.75^{a}	19.28^{b}	24.35^{a}	0.133	0.0720	0.0001	0.0001
Butyric acid	5.14^{e}	9.22^{b}	7.03^{d}	7.76^{c}	13.80^{a}	8.47^{c}	0.095	0.0001	0.0001	0.0001

[a,b] Within row, mean values with common letter(s) are not different (P>0.05).
[1]SEM, Standard error of the mean

Volatile fatty acid profiles were significantly influenced by the experimental treatments (P<0.05). Acetic acid concentration was lower in probiotic-supplemented lambs and increased with weaning age, with the 90-d weaning group exhibiting the highest values (P<0.05). A significant interaction between probiotic supplementation and weaning age was observed (P<0.05), where the probiotic-supplemented group weaned at 45 d showed the lowest acetic acid concentration. Propionic acid concentration was unaffected by probiotic supplementation (P>0.05) but varied with weaning age, being lowest at 67-d weaning group (P<0.05). Significant interactions revealed the highest propionic acid concentration in the 45-d weaned probiotic-supplemented group (P<0.001). Butyric acid concentration was significantly higher in probiotic-supplemented lambs (P<0.01) and peaked in the 67-d weaning group.

Blood metabolites

Table 4 presents the effects of probiotic supplementation and weaning age on serum biochemical metabolites and inflammatory markers. Probiotic supplementation reduced serum glucose and BUN concentrations (P<0.05), which also decreased as weaning age increased. The lowest concentrations recorded in the probiotic-supplemented group weaned at 90 d (P<0.05). Serum total protein (TP) concentration was higher in the probiotic group (P<0.05); however, weaning age had no significant effect on TP (P>0.05). Serum albumin and globulin concentrations were unaffected by treatments (P>0.05). Probiotics significantly decreased serum IL-1 and IL-6 concentrations (P<0.01), but higher weaning age increased these levels, notably in the group weaned at 90 d (P<0.01).

Discussion

Creep feed intake, average daily gain and feed conversion ratio

Effects of probiotic feeding on lamb performance has been inconsistent (Antunović et al., 2006; Titi et al., 2008; Saleem et al., 2017). Feed intake is influenced by rumen retention time, passage speed and chemical factors. Probiotics and prebiotics enhance fiber digestion by modifying the ruminal environment microbiota, improving pH, and altering microbiota (Ghazanfar et al., 2017). This leads to increased VFAs and nutrient availability, promoting FI through enhanced digestibility and cellulolytic bacteria activity in the rumen (Saleem et al., 2017).

Table 4. Effect of weaning age and probiotic supplementation on blood metabolites of lambs

	Experimental treatments									
Probiotic (g)	Pro 0			Pro 0.5			SEM[1]	*P*-value		
Weaning age (day)	45	67	90	45	67	90		probiotic	weaning age	Age × Pro
Glucose (mg/dL)	74.19[a]	72.52[ab]	70.67[bc]	72.05[ab]	70.23[bc]	68.68[c]	0.304	0.0043	0.0022	0.0033
BUN (mg/dL)	23.11[a]	20.11[bc]	17.02[d]	22.09[ab]	19.66[c]	13.06[e]	0.287	0.0084	0.0001	0.0001
Total protein (g/dL)	5.17[ab]	5.07[ab]	4.60[b]	5.80[a]	5.61[a]	5.69[a]	0.109	0.0049	0.4708	0.0585
Albumin (g/dL)	3.01	3.01	3.34	3.31	3.33	3.68	0.071	0.0470	0.1270	0.1563
Globulin (g/dL)	2.16	2.06	1.62	2.49	2.28	2.01	0.090	0.1080	0.1011	0.1978
Interleukin-1 (mg/L)	11.90[c]	12.25[bc]	13.60[a]	8.23[e]	11.05[d]	12.75[b]	0.078	0.0001	0.0001	0.0001
Interleukin-6 (mg/L)	107.15[c]	132.70[b]	157.67[a]	108.85[c]	109.78[c]	130.60[b]	1.819	0.0001	0.0001	0.0001

[a,b] Within row, mean values with common letter(s) are not different (P>0.05).
[1]SEM, Standard error of the mean

Increasing weaning age significantly increased ADG and Protoxin supplementation improved FCR. Contrary to these results, early weaning at 10 days with milk replacer and creep feed led to an increase in creep FI and better growth and health of lambs (Chai et al., 2015). Studies showed lambs on probiotics had a higher daily weight gain (El-Ashker et al., 2018; Mao et al., 2023). However, some studies reported no benefits from probiotic on DM intake, weight gain or FCR of lambs (Titi et al., 2008). Variations in results may be due to differences in growth stage, environments, administration/supplementation timelines and level, viable yeast cell number, or dietary composition. In the present study, Protoxin supplementation improved lamb performances by enhancing creep FI and BW gain. Probiotics stabilize microbiota, improve digestibility, and enhance fiber digestion via increased cellulolytic bacteria (Saleem et al., 2017). This leads to greater dry matter consumption and weight gain, while also reducing diarrhea through beneficial microorganisms in the rumen (Du et al., 2023). Thus, Protoxin affects feed intake capacity, which is crucial for growth, by supporting digestive health, nutrient absorption, and immune system development.

Rumen parameters

Probiotics improve animal health and productivity through pH stabilization and alteration of the native microbiome (Ghazanfar et al., 2017). In the present study, Protoxin supplementation did not affect pre-feeding ruminal pH: it may improve post-feeding rumen fermentation by enhancing ammonia utilization, increasing butyrate production, and modifying acetate and propionate concentrations. Probiotic supplementation also reduced ruminal NH_3-N concentration, suggesting improved ammonia utilization as also reported previous in lambs (Chen et al., 2021; Mao et al., 2023). Probiotics may enhance rumen microbial activity by incorporating NH_3-N into microbial protein and promote ruminal development by increasing total VFA and butyrate concentrations, which are key stimulators of ruminal growth (Wang et al., 2017). In agreement with these results, although dietary probiotics did not affect the ruminal pH and NH_3-N in calves, but ruminal fermentation was modified; acetic and propionic acids dcreased but butyric acid concentration increased (Wang et al., 2022). Therefore, Protoxin can stabilize ruminal pH and promote ruminal development through increased butyrate production.

Blood metabolites

Probiotic supplementation in lambs (Arab et al., 2014), goats (Saleem et al., 2017), and calves (Hosseinabadi et al., 2014) generally reduced serum glucose and BUN, although effects on glucose, cholesterol, and protein varied according to probiotic type, diet, administration route, age, and environment. Lower glucose may be due to enhanced ruminal carbohydrate fermentation, reduced starch reaching the intestine, and greater fiber digestion, while reduced BUN suggests improved ruminal nitrogen utilization and microbial protein synthesis (Antunović et al., 2006). Probiotics generally had little or no adverse effect on albumin and globulin (Saleem et al., 2017), and some studies reported increased total protein, albumin, globulin, and IgG, indicating improved immune support and protein status (Hosseinabadi et al., 2014; Abdel-Salam et al., 2014). Probiotics treatment enhanced the concentration of IgG in the serum of lambs (Chen et al., 2021) and decreased the pro-inflammatory cytokines IL-6 and TNF-α levels (Mao et al., 2023).

In the present study, total protein concentration was unaffected by weaning age, consistent with previous findings (Chai et al., 2015), while interleukin levels increased as weaning age increased. Probiotics treatment enhanced the concentration of IgG in the serum of lambs (Chen et al., 2021). In contrast, probiotics improved lamb health by lowering glucose and BUN, increasing total serum protein, and maintaining albumin and globulin levels regardless of weaning age. They also reduced pro-inflammatory cytokines such as IL-6 and TNF-α and enhanced IgG, suggesting that probiotics can ameliorate inflammation and support immune function in lambs. Therefore, probiotic supplements could be a useful nutritional support for the immune system in lambs (El-Ashker et al., 2018). It is suggested that probiotic supplements could be a useful nutritional support for the immune system in lambs.

Conclusions

In summary, Protoxin supplementation improved lamb growth performance and ruminal fermentation by lowering pH, NH_3-N, and acetic acid while increasing propionic and butyric acids. It also, reduced blood glucose, BUN, and pro-inflammatory cytokines. Later weaning further improved the weight gain, but did not affect feed conversion ratio, while increasing cytokines and NH3-N and reducing blood glucose and total protein. Therefore, Kordi lambs receiving 0.5 g Protoxin probiotic and fed by the creep feeding could be weaned at 45 days of age.

Conflict of interest

The authors declare no conflicts of interest.

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