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Growth performance, nutrients digestibility, and blood metabolites of lambs fed diets supplemented with probiotics during pre- and post-weaning period

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Objective: Two experiments were conducted to evaluate the effects on growth performance, digestibility, and blood metabolites of lambs during pre- and post-weaning period of inclusion of a commercial probiotic (PRO) containing a mixture of two strains of *Pediococcus*, *Pediococcus acidilactici* (1×10^6 colony-forming unit [cfu]/g) and *Pediococcus pentosaceus* (1.3×10^6 cfu/g), with dextrose as the carrier compound compared to a diet based on concentrate mixture and wheat straw.
Methods: In exp. 1, 24 male lambs of about 15±2.6 d age and initial body weight (BW) of 5.52±0.6 kg were randomly allocated into three groups. One group received control diet without additives, and remainders received control diet supplemented with 0.5 or 1 g PRO/lamb/d. Daily feed intake and biweekly BW were recorded. In exp. 2, five lambs, (initial BW = 29.72±1.15 kg, age = 6.54±0.32 mo) were used as experimental animals in a digestion trial. They were fed the same diets as in Exp. 1.
Results: The supplementation of PRO did not result in any significant differences in milk intake, average daily gain (ADG), or total gain between treatments during the pre-weaning period. Total dry matter intake tended to be greater ($p = 0.07$) with addition of PRO in the post-weaning diets. During post-weaning phase, the final BW, ADG, total gain, and feed conversion ratio of the lambs receiving PRO treatments tended to be greater ($p\leq0.10$) than the control group. Addition of PRO in post-weaning diet decreased ($p\leq0.01$) blood urea and cholesterol concentrations. With the exception of ether extract digestibility, all nutrients digestibility were improved with inclusion PRO in the post-weaning diets.
Conclusion: Lambs that received PRO in post-weaning diet appeared to show a better performance than lambs in pre-weaning period. Addition of the probiotic in the post-weaning diet trended towards improved dry matter intake, growth performance, feed conversion ratio, and nutrients digestibility.

Keywords: Probiotic; Growth Performance; Digestibility; Lamb

INTRODUCTION

The mortality of pre- and post-weaning lambs is one of the main factors which have a negative effect on total productivity in sheep husbandry and represents an economic loss. The time around weaning is considered as the most stressful period in the life of lambs. Sources of stress at weaning may be psychological, nutritional, and environmental [1]. Most of the changes in the ruminal microbial population can lead to health and performance problems in animals. The use of feed additives as probiotics is one of the strategies commonly used to improve the animal production and health, and potentially reduce the cost of animal breeding. Probiotics are characterized as dietary supplements containing most likely a live microorganism, which exhibit a beneficial effect on the host animal performance and health by stimulating appetite [2], improving the balance of

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the intestinal microorganisms [3], and digestion [4]. The valuable impacts of live microorganism products are associated with the improvement of microbial balance within the digestive tract, improvement of feed efficiency, and release of indigenous products [5].

The most interesting probiotic preparations that can be used as feed additives for ruminants are those with specific species of live microorganisms such as *Lactobacillus* (*L. acidophilus*, *L. bulgaricus*, *L. plantarum*, *L. casei*), *Streptococcus* (*S. faecium*) and *Bacillus* (*B. subtilis*, *B. licheniformis*, *B. cereus*) [6], which are available in different forms such as capsules, powder, paste, or granules. Probiotics also may be added to food or water as mono or mixed cultures of live microorganisms [7]. Probiotics may exert their beneficial effects to the host animal by enhancing nutrient synthesis and their bio-availability leading to higher growth performance [8], increasing rumen cellulolytic bacteria populations [9], and thus improving feed intake, growth performance, feed conversion ratio (FCR), and nutrients absorption [10,11]. Probiotics are claimed to have many benefits on the host animals. Among these effects are: improving dry matter (DM) intake, body weight (BW) gain, and FCR [12,13]. This study hypothesized that addition of probiotic in pre-weaning and post-weaning diets may be have beneficial effects to the host animals by improving rumen cellulolytic bacteria population, and thus would affect feed intake, lamb performance, digestibility, and blood metabolites. Therefore, the objective of this study was to evaluate the effect of feeding two levels of probiotic on feed intake, growth performance, diet digestibility, and certain blood metabolites in lambs during pre- and post-weaning period.

MATERIALS AND METHODS

This study was conducted at the Animal and Poultry Production Department, Faculty of Agriculture, South Valley University Sheep Farm, Qena, Egypt, during the months of December, 2014 through May, 2015. Care and handling of the animals and sample collection were approved by the South Valley University Animal Care and Use Committee.

Exp. 1, Growth study

Lambs and diets: This study was conducted on 24 Saidi lambs during pre-weaning (15 to 90 d) and post-weaning (91 to 174 d) periods using a completely-randomized design. All animals were treated for internal and external parasites and vaccinated for common infectious diseases before the experiment started.

Following colostrum consumption, 24 young male Saidi lambs of about 15±2.6 d age and an average initial BW of 5.52±0.6 kg were randomly allocated into three groups each consisting of eight animals. During the suckling period, the lambs were with the ewe under the same conditions. In addition to free suckling, the lambs were offered *ad libitum* concentrate mixture, roughage (wheat straw), and water. During the pre-weaning phase, the probiotic (PRO) was resuspended in distilled water and administered orally using a sterile syringe before suckling or morning feeding at a dose rate of 0, 0.5, and 1 g PRO/lamb/d, and the diets were named CON, PRO0.5, and PRO1, respectively. Each lamb was weaned at 90 d of age. Daily milk intakes by lambs were recorded weekly during the suckling period by measuring the difference between the lamb weight before and after suckling. After weaning, the lambs were continued with fattening and monitoring till six months of age.

During the post-weaning period, the lambs were allocated into three groups (n = 8) on the basis of initial BW (15.88±0.57 kg) and age (3±0.23 mo). The first group was fed a control diet without probiotic (CON); the second (PRO0.05) and third (PRO1) group received the control diet plus 0.5 or 1 g PRO/d, respectively. The experiment continued up to six month of age of lambs. The experimental diets were formulated to meet or exceed energy requirements according to NRC [14]. The diets were divided into two equal amounts and were fed to the lambs twice a day at 0800 and 1400 h. The control diet consisted of concentrate and wheat straw at a concentrate:roughage ratio of 80:20. Each ingredient was weighed daily and fed separately to each lamb. Concentrate, roughage, and water was offered for *ad libitum* intake throughout the trial. Probiotic was mixed with the concentrate mixture in the experimental group of the lambs. According to the supplier, the commercial probiotic supplement used in this study contains a mixture of two strains of *Pediococcus*, *P. acidilactici* (1×10^6 colony-forming unit [cfu]/g) and *P. pentosaceus* (1.3×10^6 cfu/g), with dextrose as the carrier compound. The product is intended for use with animals, birds and fish.

Measurements: Individual weighing was performed every subsequent 14 d in the morning after fasting (food and water) for 12-h during pre- and post-weaning period. Initial and bi-weekly BW were recorded on two successive days. Amounts of feed offered and refused were recorded, and daily DM intake was calculated. Furthermore, Growth performance indices were calculated as follows: average daily gain (ADG, g/lamb/d) was calculated as the difference between the final BW and initial BW divided by the number of days on feed. Total weight gain (TWG, kg) was measured as the difference between final BW and initial BW. Growth rate (GR, %) = (final BW – initial BW)/(initial BW) ×100. The FCR was calculated as the ratio between DM intake and daily gain (g of DM intake/g of BW gain).

Samples collection and chemical analyses: During the pre-weaning period, the analysis for fat, protein, lactose, and solid not fat of the milk samples was carried out using an infrared spectrometer Milko-Scan (Model 133B, N. Foss electric, Hillerød, Denmark). Representative samples of each feed ingredient (concentrate and straw) were collected every two wk and composited by month. All samples were ground in a Wiley mill (Thomas Scientific, Swedesboro, NJ, USA) to pass through a 1-mm sieve. Feed samples were subjected to proximate analysis following the standard methods of AOAC [15]. The DM, organic matter

(OM), crude fiber (CF), ether extract (EE), and ash were determined according to the procedure outlined in AOAC [15]. Total N was determined using a Kjeldahl procedure with an automated, colorimetric quantification of ammonia in digested samples [15] and multiplied by 6.25 to estimate crude protein (CP). The nitrogen-free extract (NFE) was calculated by differences. Chemical analyses of dietary ingredients and milk are reported in Table 1 and 2, respectively.

Blood sampling and analysis: Blood samples (10 mL) were collected monthly from the jugular vein from each lamb during the pre- and post-weaning period before the morning feeding. One blood sample was collected into serum separator tubes, whereas a second blood sample was collected in tubes containing 5 mg of sodium fluoride and 4 mg of potassium oxalate for subsequent glucose determination. Following collection, samples were put immediately in ice and centrifuged on the same day at 2,500 rpm for 15 minutes at 4°C to separate serum and plasma and then frozen at –20°C until analyzed. Samples were analysed for total protein, albumin, globulin, urea, cholesterol and glucose using commercially available kits. Total protein and albumin were determined by the method described by Kaplan and Szalbo [16]; Doumas et al [17], respectively, and globulin concentration was calculated by the difference between the total protein and albumin concentrations. Cholesterol was determined according to Schalm et al [18], urea was determined according to Marsh et al [19], and glucose was determined according to the method described by Trinder [20].

Exp. 2: Digestibility study

By the end of the growth study, five lambs, (initial BW = 29.72 ±1.15 kg, age = 6.54±0.32 months) were randomly selected from each treatment group and assigned in individual digestibility cages. Dietary treatments included 0, 0.5, and 1 g/lamb/d inclusion of probiotic in the diets. A digestion trial consisted of 15 d for diets adaptation and seven d feces collection period. Lambs were fed concentrate and straw separately as *ad libitum* intake. During the collection period, total feces were collected. The daily fecal collections were weighed and mixed thoroughly by hand and subsamples representing 10% of daily fecal production from each lamb were frozen at –5°C until being composited for the complete period collection. Representative samples of each daily collection of diets, orts and feces were pre-dried in drying oven at 60°C to 70°C for 48 h and ground through 1 mm mill screen openings and were stored for further analysis. Samples were analyzed for DM, OM, CP, EE, CF, and ash contents according to AOAC [15] methods, while NFE was calculated by differences.

Table 1. Chemical composition of ingredients and diet used in experiment 1 and 2 (on DM basis, %)

Item	DM%	OM	CP	EE	CF	NFE	Ash
Concentrate mixture[1)]	88.56	91.05	14.55	2.80	13.83	59.87	8.95
Wheat straw	92.16	82.45	3.6	1.43	36.07	41.35	17.55
Diet	89.30	89.29	12.31	2.52	18.39	56.07	10.71

DM, dry matter; OM, organic matter; CP, crude protein; EE, ether extract; CF, crude fiber; NFE, nitrogen free extract.
[1)] Concentrate mixture contains: 40.0% yellow corn, 15.0% wheat bran, 15.0% cottonseed meal, 12.5% soybean meal, 15.0% molasses, 1.0% calcium carbonate, 1.0% sodium chloride, and 0.5% mineral plus vitamins additives.

Statistical analysis

All data were analyzed as a complete randomized design using the PROC MIXED procedure of [21]. The statistical model was: $Y_{ij} = \mu+T_i+C_j+E_{ij}$, in which Y_{ij} is observed measurement, μ is the overall mean, T_i is the fixed effect of treatments (i = 1, 2, and 3), C_j is the random effect of lamb within treatment, and E_{ij} is the residual error. Treatment means were computed with the LSMEANS option.

Results are presented as least square means±standard error of the mean. Differences between treatment means were evaluated using Orthogonal to compare i) Control treatment (CON) vs all probiotic treatments (PRO0.5 and PRO1); ii) PRO0.5 vs PRO1. Differences for comparisons were considered to be significant when p≤0.05 and tendencies included p>0.05 and ≤0.10.

RESULTS

Intake and growth performance

Intake and growth performance of lambs fed experimental diets

Table 2. Milk composition on different observation days during pre-weaning period

Item	Diet[1)]			SEM	Contrast[2)], p-values	
	CON	PRO0.5	PRO1		CON vs PRO	PRO0.5 vs Pro1
Milk composition (%)						
Fat	5.73	5.69	5.65	0.28	0.81	0.89
Protein	4.78	4.72	4.76	0.21	0.86	0.90
Lactose	4.31	4.37	4.28	0.16	0.82	0.41
SNF	9.85	9.83	9.81	0.22	0.91	0.93
TS	15.58	15.52	15.45	0.32	0.82	0.89
Ash	0.76	0.75	0.76	0.06	0.77	0.32

SEM, standard error of the mean; SNF, solid not fat; TS, total solids.
[1)] Diets: CON, control diet; PRO0.5, CON plus 0.5 g probiotic; PRO1, CON plus 1 g probiotic. [2)] Contrasts, CON vs Probiotic (PRO0.5 and PRO1); PRO0.5 vs PRO1.

Table 3. Effect of probiotic (PRO) supplementation on growth performance, average daily gain, and total weight gain of lambs during pre-weaning period

Item	Diet[1)]			SEM	Contrast[2)], p-values	
	CON	PRO0.5	PRO1		CON vs PRO	PRO0.5 vs PRO1
No. of animals	8	8	8	-	-	-
Milk intake (g/lamb/d)	729.17	760.90	764.00	50.76	0.35	0.93
Initial weight (kg)	5.53	5.60	5.42	0.61	0.97	0.84
2nd wk (kg)	6.27	6.32	5.92	0.68	0.86	0.69
4th wk (kg)	7.75	8.00	7.75	0.78	0.90	0.83
6th wk (kg)	9.18	9.70	9.11	0.83	0.79	0.69
8th wk (kg)	10.72	11.16	11.83	1.00	0.53	0.65
10th wk (kg)	12.27	12.78	13.58	1.03	0.48	0.60
Final weight3) (kg)	14.00	14.54	15.50	1.08	0.45	0.55
Growth rate (%)	160.14	167.23	191.53	26.42	0.41	0.38
ADG (g/lamb/d)	100.79	106	120	9.09	0.28	0.32
TWG (kg)	8.47	8.94	10.08	9.16	0.28	0.32

SEM, standard error of the mean; ADG, average daily gain; TWG, total weight gain.
1) Diets: CON, control diet; PRO0.5, CON plus 0.5 g probiotic; PRO1, CON plus 1 g probiotic.
2) Contrasts, CON vs Probiotic (PRO0.5 and PRO1); PRO0.5 vs PRO1. 3) Final weight, 174 d of study.

during pre- weaning and post-weaning period are shown in the Table 3 and 4, respectively. In the pre-weaning period, the analysis of milk samples on the test days indicated that lambs in all treatment groups received milk with a similar chemical composition (Table 2). The supplementation of PRO did not have any significant effects on daily milk intake, live weight, ADG, or TWG of lambs in pre-weaning period (Table 3).

In the post-weaning period, total DM intake tended to be higher ($p = 0.07$) with PRO supplementation when compared to the CON group. The DM intake was not affected between the two PRO treatments ($p = 0.59$). The initial BW was not significantly ($p = 0.61$) different between lambs in all treatment groups. The final BW, ADG, TWG, and FCR of the lambs receiving PRO treatments tended to be greater ($p \leq 0.10$) compared with the CON group. A comparison between the PRO groups shows that lambs receiving a high level of PRO tended to have greater final BW ($p = 0.16$) compared with those lambs fed the low amount of PRO.

Although not statistically significant, the present results showed that lambs receiving 1 g PRO/d had the numerically highest live BW, ADG, TWG, and GR compared to control group and PRO0.5. Moreover, FCR expressed as g DM intake/g gain was numerically lower ($p = 0.24$) for lambs fed 1 g PRO/d compared to those lambs fed control or 0.5 g PRO/d (6.71 vs 7.89 and 7.40, respectively).

Blood metabolites

Pre- and post-weaning blood metabolites concentrations are presented in Table 5. During pre-weaning period, serum total protein concentration was increased ($p<0.05$) with PRO supplementation compared to the CON treatment. With the exception of serum total protein concentration, all blood metabolites were

Table 4. Dry matter intake, growth performance, and feed conversion ratio of lambs fed control (CON), PRO0.5, and PRO1 diets during post-weaning period

Item	Diet[1)]			SEM	Contrast[2)], p-values	
	CON	PRO0.5	PRO1		CON vs PRO	PRO0.5 vs PRO1
No. of animals	8	8	8	-	-	-
Total DMI (g/lamb/d)	1,115.00	1,123.33	1,126.67	4.24	0.07	0.59
Initial weight (kg)	15.43	15.72	16.48	1.04	0.61	0.61
2nd wk (kg)	16.75	16.62	17.68	1.02	0.73	0.47
4th wk (kg)	18.67	18.42	20.17	1.06	0.64	0.26
6th wk (kg)	21.08	21.58	22.83	1.05	0.39	0.42
8th wk (kg)	23.50	24.25	25.63	0.99	0.25	0.34
10th wk (kg)	25.83	26.58	28.25	1.03	0.23	0.27
Final weight3) (kg)	27.5	28.75	30.66	0.93	0.07	0.16
Growth rate (%)	81.65	84.65	88.73	8.93	0.65	0.75
ADG (g/lamb/d)	143.65	155.16	168.85	8.04	0.08	0.25
TWG (kg)	12.07	13.03	14.18	0.68	0.08	0.25
F:G	7.89	7.40	6.71	0.41	0.10	0.24

SEM, standard error of the mean; DMI, dry matter intake; ADG, average daily gain; TWG, total weight gain; F:G, g of DMI/g ADG.
1) Diets: CON, control diet; PRO0.5, CON plus 0.5 g probiotic; PRO1, CON plus 1 g probiotic.
2) Contrasts, CON vs Probiotic (PRO0.5 and PRO1); PRO0.5 vs PRO1. 3) Final weight, 180 d of study.

Table 5. Effects of probiotic (PRO) supplementation on pre- and post-weaning blood metabolites

Item	Diet[1)]			SEM	Contrast[2)], p-values	
	CON	PRO0.5	PRO1		CON vs PRO	PRO0.5 vs PRO1
Total protein (g/dL)						
Pre-weaning	6.11	6.29	6.24	0.15	0.02	0.46
Post-weaning	7.59	7.47	7.72	0.14	0.91	0.19
Albumin (g/dL)						
Pre-weaning	3.13	3. 22	3.03	0.18	0.98	0.47
Post-weaning	3.68	4.06	3.92	0.17	0.26	0.29
Globulin (g/dL)						
Pre-weaning	2.98	3.07	3.21	0.19	0.50	0.62
Post-weaning	3.91	3.42	3.80	0.21	0.40	0.10
Glucose (mg/dL)						
Pre-weaning	63.15	62.90	62.3	3.02	0.60	0.62
Post-weaning	72.25	72.87	72.60	3.14	1.00	0.89
Urea (mg/dL)						
Pre-weaning	27.38	26.88	26.63	0.70	0.48	0.81
Post-weaning	35.17	34.38	33.99	0.22	0.003	0.23
Cholesterol (mg/dL)						
Pre-weaning	74.08	73.30	72.89	2.56	0.76	0.91
Post-weaning	85.40	84.88	83.95	2.29	0.04	0.01

SEM, standard error of the mean.
1) Diets: CON, control diet; PRO0.5, CON plus 0.5 g probiotic; PRO1, CON plus 1 g probiotic. 2) Contrasts, CON vs Probiotic (PRO0.5 and PRO1); PRO0.5 vs PRO1.

not significantly different between PRO and CON treatments in pre-weaning period. Probiotic supplementation in post-weaning lambs diet did not change (p>0.05) blood constituents of total protein, albumin, globulin, and glucose levels, however blood urea and cholesterol concentrations were significantly decreased with PRO supplementation (p<0.003), (p<0.04), respectively. A comparison between the two PRO treatments showed that lambs receiving diets supplemented with 1 g PRO/d had lower (p = 0.01) concentration of cholesterol compared to lambs fed 0.5 g PRO/d. With the exception of blood urea, all blood metabolites did not differ between the treated groups during the post-weaning period.

Exp. 2: Digestibility study

Nutrients digestibility and nutritive values of experimental diets are presented in Table 6. With the exception of EE digestibility, the digestibility of DM, OM, CP, CF, and NFE were improved (p≤0.01) in lambs receiving PRO treatments compared to CON treatment. A comparison between the two PRO treatments showed that there was no significant difference in EE, CF, and NFE digestibility between PRO treatments; however digestibility of DM, OM, and CF was improved (p<0.01) by PRO1 supplementation compared to PRO0.5. The nutritive values, expressed as total digestibility nutrients (TDN) and digestible crude protein (DCP), found that the lowest TDN and DCP values were shown by CON (7.77% and 57.95%, respectively), while the highest values were recorded by lambs receiving 0.5 and 1 g PRO/d (8.432%, 9.21% and 62.32%, 64.28%, respectively), and a significant difference (p<0.0001) was found between PRO and CON treatments. Within probiotic groups, a significant difference

Table 6. Effect of feeding probiotic (PRO) supplemented diet to lambs on digestibility and nutritive value of experimental treatments

Item	Diet[1)]			SEM	Contrast[2)], p-values	
	CON	PRO0.5	PRO1		CON vs PRO	PRO0.5 vs PRO1
Nutrients digestibility (%)						
DM	62.56	64.01	66.39	1.71	0.008	0.03
OM	64.41	65.28	67.29	2.41	0.002	0.004
CP	63.18	68.52	74.88	2.87	<0.0001	0.0002
CF	65.18	65.22	66.33	1.45	0.08	0.63
EE	51.32	54.25	55.26	2.85	0.55	0.36
NFE	66.07	71.73	73.40	1.25	0.0007	0.37
Nutritive value (%)						
DCP	7.77	8.43	9.21	0.11	<0.0001	0.0002
TDN	57.95	62.32	64.28	2.80	<0.0001	0.10

DM, dry matter; OM, organic matter; CP, crude protein; CF, crude fiber; EE, ether extract; NFE, nitrogen free extract; DCP, digestible crude protein; TDN, total digestible nutrients.
1) Treatments: CON, control diet; PRO0.5, CON plus 0.5 g probiotic; PRO1, CON plus 1 g probiotic. 2) Contrasts, CON vs Probiotic (PRO0.5 and PRO1); PRO0.5 vs PRO1.

(p = 0.0002) and a tendency (p≤0.10) were detected in DCP and TDN values between PRO treatments, respectively.

DISCUSSION

Exp. 1: Growth study

Intake and growth performance: The lack of effects of PRO supplementation on lamb performance in the pre-weaning period, was probably due to none of the treatments significantly affecting milk intake (Table 3). The lack of effects of PRO supplementation on milk intake, live weight, daily gain, and total gain in pre-weaning period are consistent with a study by Ataşoğlu et al [22] who reported that probiotic supplementation did not affect milk intake or weight gain during pre-weaning period in goat kids. In our case, during post-weaning period, DM intake tended to be higher with PRO supplementation, and this may be due to improved nutrients availability and their quick digestion by rumen microorganisms with PRO supplementation. Moreover, a positive effect of addition of PRO on feed intake during post-weaning period may be due to an increasing number and proportion of cellulolytic bacteria in the rumen [9] and improved ruminal pH [13], which would be reflected by improved feed intake and fiber digestibility of lambs. In the present study, supplemented PRO was mixed with concentrate in post-weaning period which was similar to a study by Mukhtar et al [23] who reported that DM intake tended to be increased when lambs were fed concentrate supplemented with probiotic compared to those lambs fed concentrate only. Addition of probiotic has been previously reported to improve feed intake with lambs [24,10]. However, Titi et al [25] reported that DM intake was not affected when lambs were fed diets supplemented with probiotic.

Positive effects of inclusion of PRO on growth performance are expected to be accompanied by improvements in feed intake [22]. In the present results, addition of PRO improved the lambs performances by enhancing BW gain, TWG, GR, and reducing FCR in the post-weaning period which a companied by a tendency to increase DM intake. The levels of the supplemented probiotic used in the present study were similar to those levels used by Arab et al [26] who reported that lambs receiving 0.5 and 1 g probiotic/kg feed have significantly (p<0.05) greater BW compared to the control group. Other studies reported that improvement in growth performance with probiotic supplementation may be due to a higher feed consumption and better feed efficiency [24], and improving DM intake, digestibility of CF and crud protein, and reduced incidence of diarrhoea due to increase number of beneficial microorganisms in the rumen [27]. Another possible reason for improved growth performance with addition of probiotic may be that, during the post-weaning period, lambs are transferring from milk diet provided by the ewe to forage or grain based diet which stimulates rumen development. Ataşoğlu et al [22] reported that changes in the intake capacity of young lambs for solid feeds can affect growth performance particularly in the post-weaning period.

In the present study, FCR was improved by PRO supplementation during post-weaning period, and this may be due to improved feed intake and nutrients digestibility. Improved FCR with PRO supplementation has been reported with calves [28] or lambs [29,10,30]. A recent study by El-Katcha et al [31] reported that growing lambs receiving *pediococcus* spp (Bacteria probiotic) supplementation in drinking water had a higher final BW and weight gain, and better feed conversion efficiency compared to control group. On the other hand, probiotic supplementation had no effect on DM intake, live weight gain, or FCR of steers [32] or lambs [25]. Differences in the results of these experiments and our results may be due to the differences in the animal models used, growth stage, environment, administra/supplementation timelines and level, viable yeast cell number, or composition of animal diets [11].

Blood metabolites: The lack effects of probiotic supplementation on total protein, albumin, globulin and glucose concentrations in post-weaning period are in agreement with others, Antunovic et al [10]; El-Katcha et al [31] who reported that no significant differences in total protein, albumin, globulin, and glucose levels on growing lambs or goats fed diets containing probiotic. Blood glucose concentration was not changed when lamb were fed diets supplemented with probiotics [30]. However, Abdel-Salam et al [12] found that blood concentrations of total protein, albumin, and globulin were greater when lambs received probiotics treatments compared to the control diets. Whereas, Arab et al [26] reported that glucose, total protein, albumin, and cholesterol concentrations were decreased significantly (p<0.05) in lambs receiving 0.5 or 1 g probiotic/kg feed compared to control group. Direct-feed microbial supplements decreased blood cholesterol levels [33], probably due to microbial feed additives reducing the absorption of lipid from the intestines by deconjugation. In the present study, feeding of PRO improved animal health status by not affecting the level of blood glucose while decreasing cholesterol in blood serum. Probiotic groups had lower levels of urea in the blood, probably due to better utilization of nitrogen from food in the rumen with probiotic supplementation. Similar results were observed in the previous studies, Antunovic et al [24,10]; Ding et al [30] in which the concentrations of blood urea were decreased in response to probiotic supplementation compared to the control group.

Exp. 2: Digestibility study

With the exception of EE digestibility, addition of probiotic in the diets result in improved nutrients digestibility of DM, OM, CP, CF, and NFE. In the present study, lambs were fed a highly digestible concentrate diet, which may have resulted in positive effects of PRO supplementation on digestibility. Another possibility could be that probiotic supplementation may have increased ruminal cellulolytic microbial populations and improved rumen pH [13]. The present results are agreement with other studies, Haddad and Goussous [29] reported that *Awassi* lambs fed diet supplemented with probiotic (yeast culture, YC) at levels 0, 3, and 6 g/d of YC, resulted in improve nutrients digestibility of DM, OM, and apparent CP for 3 g/d group compared to other groups. Mukhtar et al [23] reported that DM and CP digestibility were higher in lambs fed concentrate with probiotic than lambs fed concentrate only, but the difference was not significant. Moreover, Hillal et al [34] reported that supplementing the diet of growing lambs with probiotic improved the digestibility of DM, OM, CP, CF, EE, and NFE compared to the control, but the differences in nutrients digestibility were not significant except for CP digestibility. On the other hand, supplementing the diet of weaned lambs [30] or goats [11] with probiotic did not affect the digestibility of DM, OM, and CP compared to control group. Moreover, Titi et al [25] reported that using probiotics (yeast culture) in *Awassi* lambs improved OM digestibility, with no effect on DM and CP digestibility. Differences in the results of these experiments may be because of differences in the animal models used, environment, method of administration, level and type of addition of probiotic, or supplementation timelines [11].

CONCLUSION

Lambs receiving PRO in post-weaning diet appeared to show a better performance than lambs in pre-weaning period. Supplementation of probiotic in pre-weaning period did not improve feed intake or lamb performance. However, inclusion of probiotic in post-weaning diets tended to improve DM intake, BW, daily gain, and decreasing FCR. Also feeding probiotic improved animal health status by not affecting the level of blood glucose while decreasing cholesterol concentration in the blood.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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