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Effect of synbiotic supplementation on growth performance, nutrient digestibility, rumen fermentation, and blood metabolites in Arabi lambs

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Abstract

Background. A synbiotic is a product of living microorganisms and their metabolites, which when consumed can benefit the health of the host animal by affecting the microbial balance in the stomach or gut.

Purpose. To assess the growth performance and nutrient utilization of diet supplementation with synbiotic to Arabi lambs.

Methodology. Thirty male lambs, approximately four months old, were used in a 105-day feeding trial, which included a 15-day adaptation period. Animals were randomly and evenly allocated into three dietary groups. The control group received a basal diet composed of 40% concentrate and 60% alfalfa hay. The second and third groups were offered the same basal diet supplemented with 3 kg/ton and 5 kg/ton synbiotic, respectively. Parameters measured included body weight, total and daily weight gain, feed intake, feed conversion ratio, and apparent nutrient digestibility.

Results. Synbiotic supplementation at 3 kg/ton and 5 kg/ton increased final body weight by 15.50% and 14.28%, respectively, compared with the control group. Likewise, total and daily weight gains improved by 40.19% and 33.83%, respectively. Feed intake showed a slight increase (2.11%), whereas feed conversion ratio improved markedly, decreasing by 24.97% and 22.32% in the 3 kg and 5 kg synbiotic groups, respectively. Digestibility coefficients of dry matter, organic matter, crude protein, acid detergent fiber (ADF), and neutral detergent fiber (NDF) were significantly higher ($p < 0.05$) in both supplemented groups.

Conclusion. The moderate synbiotic supplementation (3 kg/ton) optimizes nutrient utilization, enhances growth performance, and improves feed efficiency in Arabi lambs under Basrah field.

Keywords: Arabi lambs; synbiotic; growth performance; rumen fermentation; nutrient digestibility; blood metabolites

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Introduction

A synbiotic is a substance derived from living microorganisms and their byproducts that can enhance the host animal's health by improving the microbial balance in its gut or digestive tract [1]. It refers to pre-prepared or extracted microbial media, enzymatic preparations, or any combination of these terms [2; 3]. The U.S. Food and Drug Administration has dubbed synbiotic as direct-fed microbial, thereby limiting the definition to living microorganisms naturally present in the gastrointestinal tract of animals that are incorporated into the diets of small or large animals [4-6]. This accelerates the establishment of microbial equilibrium in the normal state, bolstering defense mechanisms, stimulating the immune system, improving health, and promoting productive performance instead of focusing on disease resistance [7-9]. The synbiotic is used in animal nutrition not only to achieve the microbial balance of the intestinal flora in the gut, which is inherently present, but also to rectify any imbalance, especially when animals encounter stressors, such as high temperatures, disease injury, dietary alterations, or weaning, all of which adversely affect productive performance [10]. The synbiotic has been shown to restore the microbial balance of the intestinal flora to its normal state through various mechanisms, such as improving the digestibility coefficient of nutrients [11], decreasing the viscosity of gut contents, and reducing the transit of substances in it [12]. Moreover, the synbiotic can enhance the activity of vital enzymes, vitamins, and amino acids during digestion, which improves the performance of the intestinal flora and the rumen [13].

The synbiotic enhances fermentation in the rumen and stabilizes its pH, positively influencing the growth of microorganisms and their performance, particularly cellulolytic bacteria, while serving as a vital source of energy and

protein for microbial growth [14]. Consequently, feed digestion improves, feed intake increases, and feed conversion efficiency is enhanced [15]. The supplementation with synbiotics boosts the fiber digestion in rumen and increases the digestion of total dry matter, acidic detergent fibre (ADF), and neutral detergent fibre (NDF) depending on the diet especially its fibre content [16].

It was found that the supplementation of probiotics or a synbiotic to Awassi and Barki lambs had a positive effect on feed conversion ratio, nutrient digestibility and rumen fermentation efficiency [17; 18]. But, few data are available on adaptable breed of lamb – Arabi which has moderate growth performance. The study was designed to determine the effect of different levels of inclusion of synbiotic on growth performance, digestibility, rumen fermentation and blood metabolites in southern Iraqi conditions. The objective of this study was to investigate the effects of the inclusion of different levels of synbiotic on growth performance, digestibility, rumen fermentation and blood metabolites in Arabi lambs when reared in the southern Iraqi condition.

Materials and methods

Experimental Design and Animals

The experiment was conducted at the Animal Field, College of Agriculture, University of Basrah. Thirty healthy Arabi male lambs aged (3–4) months with an average initial weight of 17.25 ± 1.14 kg were randomly assigned to three treatments ($n=10$ each). The trial lasted 105 days, including 15 days for adaptation.

Diet Composition and Treatments

All lambs received a basal diet composed of 60% alfalfa hay and 40% concentrate mix (barley 54%, bran 30%, corn 10%, soybean meal 5%, vitamins + minerals 1%). Treatment groups: Control (no additive), S3 (3 kg/ton synbiotic), and S5 (5 kg/ton synbiotic). The synbiotic contained viable *Bacillus subtilis*, *Bacillus licheniformis*, and *Enterococcus faecium* cultures, plus amino acids, peptides, and whey-based carriers. The chemical composition and proportions of the feed substances of the concentrated diet and alfalfa hay are shown in (Table 1). The concentrated diet consisted of 54% barley, 30% bran, 10% ground yellow corn, 5% soybeans, and 1% vitamins and mineral salts. The concentrated diet was administered as 40% and alfalfa hay at 60%. The control group received a diet with no synbiotic additive. However, the two other groups received the control diet supplemented with either 3 or 5 gm/ton synbiotic.

Table 1.

Chemical composition of feed materials used in the study (%)

Nutrient	Alfalfa hay	Concentrate
Dry matter	91.11	90.24
Crude protein	16.40	14.15
Ether extract	1.28	2.38
Crude fiber	32.28	17.47
Ash	6.75	4.77
NFE	34.40	56.80

Metabolizable energy was calculated according to MAFE (1975) = 11.26 MJ/ kg dry matter, NFE= Nitrogen free extract

Performance and Digestibility Measurements

Lambs were weighed weekly, feed intake was recorded daily, and feed conversion ratio (FCR) calculated. A 5-day digestibility trial was conducted using grab sampling. Feed and feces were analyzed for DM, OM, CP, NDF, and ADF following AOAC methods [19].

Rumen Fermentation and Blood Analysis

Rumen liquor samples were collected 3 h post-feeding. pH was measured immediately. Ammonia-N was analyzed using the phenol-hypochlorite method, and volatile fatty acids were determined by gas chromatography. Blood samples were collected before feeding, and serum analyzed for glucose, protein, urea, and cholesterol using commercial diagnostic kits (Biolabo, France).

Quantitative Real-Time PCR (qPCR) Enumeration of Rumen Bacteria

To quantify major ruminal bacterial groups, genomic DNA was extracted from rumen liquor samples using the Qiagen DNeasy PowerSoil Kit (Qiagen, Germany) following the manufacturer's protocol. The concentrations and purity of DNA was assessed spectrophotometrically at 260/280 nm. An Applied Biosystems StepOnePlus PCR machine equipped with SYBR Green Master Mix (Thermo Fisher Scientific, USA) was used for quantitative real-time PCR (qPCR). Specific primers to 16S rRNA gene were used for total bacteria, *Fibrobacter succinogenes*, *Ruminococcus flavefaciens* and *Bacillus* spp. Thermal cycling conditions: 95°C for 3 min and 40 cycles of 95°C for 15 s and 60°C for 30 s. Specificity of amplicons was confirmed by melt curve analysis. The relative abundance of bacterial species was obtained by the Livak and Schmittgen method [20] using total 16S rRNA copies as reference. Data were reported as Log₁₀ (copies/mL of rumen fluid).

Economic Evaluation and Statistical Analysis

Feed cost/kg gain was determined using market prices. The net revenue and profitability index were obtained. The data obtained were subjected to one-way ANOVA (SPSS v.26) and the means were compared with Tukey's test ($p < 0.05$).

Results and discussion

Growth Performance

Growth parameters were significantly improved in lambs fed with the addition of synbiotic to their Arabi lamb feed (Table 2). The 3 kg/t synbiotic group had the highest ($p < 0.05$) final body weight and average daily gain when compared to the control group. The feed conversion ratio (FCR) is improved by around 25%, which represents improved feed efficiency and utilization of nutrients. However, no significant difference in feed intake indicated that the increased growth was due to more efficient use of nutrients rather than to increased feed intake. The results are consistent with those of other studies demonstrating that use of the synbiotic enhanced the growth rate and FCR of small ruminants [17; 21]. Mechanisms include the colonization of beneficial bacteria like *Bacillus subtilis* and *Enterococcus faecium* that generate enzymes that enhance nutrient breakdown [11]. Furthermore, bacteria in the gut are balanced, meaning there are fewer bad bacteria; this helps maintain integrity of the gut and better absorption of nutrients [1].

Table 2.
Growth performance of Arabi lambs fed synbiotic-supplemented diets (Mean $\pm$ SE)

Parameter	Control	3 kg Synbiotic	5 kg Synbiotic
Initial body weight (kg)	17.25 $\pm$ 0.33 ^a	17.36 $\pm$ 0.41 ^a	17.27 $\pm$ 0.39 ^a
Final body weight (kg)	28.86 $\pm$ 1.55 ^b	33.33 $\pm$ 2.04 ^a	32.44 $\pm$ 1.72 ^{ab}
Total gain (kg)	11.61 $\pm$ 0.42 ^b	15.97 $\pm$ 0.53 ^a	15.17 $\pm$ 0.49 ^{ab}
Average daily gain (g/day)	110.6 $\pm$ 5.2 ^b	152.1 $\pm$ 6.7 ^a	144.5 $\pm$ 6.3 ^{ab}
Dry-matter intake (kg/day)	0.90 $\pm$ 0.04 ^a	0.91 $\pm$ 0.05 ^a	0.92 $\pm$ 0.04 ^a
Feed conversion ratio (kg feed/kg gain)	8.11 $\pm$ 0.38 ^a	5.91 $\pm$ 0.27 ^b	6.34 $\pm$ 0.31 ^b

^{ab}Means within the same row with different superscripts differ significantly ($p < 0.05$)

Nutrient Digestibility

Apparent digestibility of DM, OM, CP, NDF and ADF were significantly ($p < 0.05$) higher in the synbiotic than in the control group (Table 3). The digestibility coefficients were highest for the 3 kg/ton treatment which indicates great-

er microbial activity and rumen fiber degradation. The increase in digestibility of NDF and ADF indicated that synergistic action of the bacteria contributes in an increase in cellulolytic and fibrolytic enzyme activity which led to better use of fibrous part of the diet. A similar increase in digestibility was reported in Awassi lambs by Tabaghdeh et al. who found a (3–5) % increase following probiotic supplementation [21]. This is probably due to increased cellulolytic bacteria in the rumen and stabilization of the pH, improving the fermentation conditions [13]. In accordance, Direkvandi et al. concluded that microbial additives increased both the nitrogen retention and microbial protein synthesis [22], which was in line with the present study where a higher CP digestibility was found.

Table 3.

Apparent nutrient digestibility coefficients (%) (Mean $\pm$ SE)

Parameter	Control	3 kg Synbiotic	5 kg Synbiotic
Dry matter (DM)	71.12 $\pm$ 0.84 ^b	73.98 $\pm$ 0.67 ^a	72.84 $\pm$ 0.76 ^{ab}
Organic matter (OM)	73.04 $\pm$ 0.89 ^b	75.46 $\pm$ 0.72 ^a	74.81 $\pm$ 0.79 ^{ab}
Crude protein (CP)	68.92 $\pm$ 0.77 ^b	71.83 $\pm$ 0.65 ^a	70.66 $\pm$ 0.73 ^{ab}
Neutral detergent fiber (NDF)	58.64 $\pm$ 0.91 ^b	62.87 $\pm$ 0.82 ^a	61.43 $\pm$ 0.84 ^{ab}
Acid detergent fiber (ADF)	55.71 $\pm$ 0.86 ^b	59.66 $\pm$ 0.77 ^a	58.94 $\pm$ 0.81 ^{ab}

^{ab}Means within the same row with different superscripts differ significantly ($p < 0.05$).

Rumen Fermentation Characteristics

The supplementation of synbiotic has positive effects on the rumen fermentation parameters (Table 4). Both synbiotic levels reduced the concentration of ruminal ammonia-N and acetate: propionate ratio, and increased the proportion of propionate as well as total volatile fatty acids (VFA) ($p < 0.05$). The 3 kg/ton treatment resulted in the most even fermentation profile, suggesting optimal microbial efficiency and energy production.

The total VFA and propionate are increased, indicating increased carbohydrate fermentation and more energy available to the host. In ruminants, the primary gluconeogenic substrate is propionate, and an increase in this substrate directly contributes to growth and body weight gain [9; 15]. The lower ammonia-N values can be attributed to improved nitrogen utilization, which may be related to higher microbial protein production and lower deamination of amino acids [11]. The present results corroborate with those of Alagawany et al. who observed the improvement in rumen fermentation balance and the reduction in nitrogen losses in goats and sheep with the use of a synbiotic [1].

Table 4.

Rumen fermentation parameters (Mean $\pm$ SE)

Parameter	Control	3 kg Synbiotic	5 kg Synbiotic
pH	6.52 $\pm$ 0.04 ^a	6.48 $\pm$ 0.03 ^a	6.50 $\pm$ 0.03 ^a
Ammonia-N (mg/dL)	21.8 $\pm$ 0.55 ^a	19.9 $\pm$ 0.48 ^b	20.3 $\pm$ 0.51 ^b
Total VFA (mmol/L)	92.4 $\pm$ 2.6 ^b	105.8 $\pm$ 2.9 ^a	101.7 $\pm$ 2.8 ^{ab}
Acetate (%)	65.1 $\pm$ 1.1 ^a	61.3 $\pm$ 1.0 ^b	62.0 $\pm$ 1.0 ^b
Propionate (%)	21.4 $\pm$ 0.7 ^b	25.9 $\pm$ 0.8 ^a	24.8 $\pm$ 0.8 ^{ab}
Acetate: Propionate	3.04 $\pm$ 0.09 ^a	2.37 $\pm$ 0.08 ^b	2.50 $\pm$ 0.08 ^b

^{ab}Means within the same row with different superscripts differ significantly ($p < 0.05$).

Rumen Bacterial Enumeration

The numbers of the main groups of rumen bacteria differed significantly ($p < 0.05$) between treatments (Table 5 and Figure 1). The 3 kg/ton synbiotic group had the highest counts of total bacteria and significant higher counts of *Fibrobacter succinogenes* and *Ruminococcus flavefaciens* than those of the control group. The number of *Bacillus* spp. also increased significantly in both the supplemented groups, indicating good colonization of probiotics. The microbial density in the 5 kg/ton treatment was similar but reduced compared with that of the 3kg/ton treatment indicating that over supplementation can have no further beneficial effect on microbial density.

Table 5.

Rumen bacterial population ($\log_{10}$ copies/mL, Mean $\pm$ SE)

Bacterial group	Control	3 kg Synbiotic	5 kg Synbiotic
Total bacteria (16S rRNA)	8.52 $\pm$ 0.06 ^b	9.12 $\pm$ 0.05 ^a	8.97 $\pm$ 0.04 ^{ab}
<i>Fibrobacter succinogenes</i>	6.78 $\pm$ 0.07 ^b	7.26 $\pm$ 0.06 ^a	7.12 $\pm$ 0.05 ^{ab}
<i>Ruminococcus flavefaciens</i>	6.55 $\pm$ 0.08 ^b	7.10 $\pm$ 0.07 ^a	6.89 $\pm$ 0.06 ^{ab}
<i>Bacillus</i> spp.	5.84 $\pm$ 0.09 ^b	6.42 $\pm$ 0.07 ^a	6.35 $\pm$ 0.08 ^a

^{ab}Means within the same row with different superscripts differ significantly ($p < 0.05$).

The higher numbers of cellulolytic species (*Fibrobacter succinogenes* and *Ruminococcus flavefaciens*) in the lambs fed the synbiotics suggests improved cellulolytic potential of the rumen. This is consistent with the greater digestibility coefficients that were found in (Table 2). The increase in *Bacillus* spp. count shows the survival and colonization effectiveness of the *Bacillus* spp. probiotics in the rumen, helping to stabilize the rumen ecosystem. This finding was corroborated by Zhou et al., who saw increased fibrolytic bacteria and de-

creased ammonia levels in rumen when probiotic containing *Bacillus* species were fed to sheep [23] and by Nueraihemaiti et al., where feeding of probiotic *Bacillus* species to sheep diets resulted in higher levels of fibrolytic bacteria and lower levels of ruminal ammonia [24]. The present findings indicate that the synbiotic supplementation has the ability to create an optimal balance of microorganisms by promoting a shift towards the growth of beneficial fermentative species, which leads to better use of nutrients and animal performances.

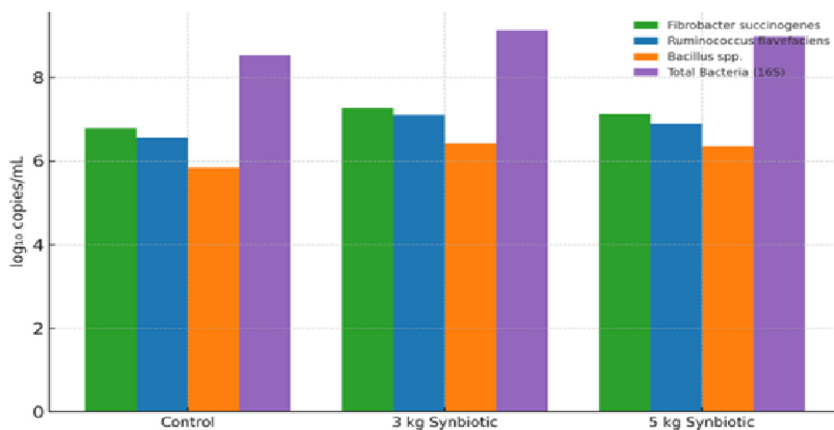


Fig. 1. Rumen bacterial abundance ($\log_{10}$ copies/mL) in Arabi lambs fed control and synbiotic-supplemented diets (3 kg/ton and 5 kg/ton). Bars represent means $\pm$ SE for total bacteria (16S rRNA), *Fibrobacter succinogenes*, *Ruminococcus flavefaciens*, and *Bacillus* spp

Correlation between production traits and rumen microbial populations

Population, increased total and cellulolytic bacterial counts were positively related to improved growth performance in Arabi lambs (Table, 6). Higher abundance of microorganisms was strongly related ($p < 0.05$) with final body weight ($r \approx 0.72$), total weight gain ($r \approx 0.78$), and average daily gain ($r \approx 0.81$), demonstrating that better microbial activity resulted in greater efficiency in nutrient utilization. In contrast, feed conversion ratio negatively correlated ($r \approx -0.69$) with total bacterial count and confirmed the improved microbial fermentation had decreased feed required per unit gain. Dry-matter intake showed a small non-significant correlation and demonstrated that supplementation of synbiotics mainly increased nutrient digestibility rather than intake volume. These results indicate a strong relationship between rumen microbiota and growth performance in lambs after receiving dietary synbiotics.

Production traits (growth and feed efficiencies) are physiologically associated to rumen micro-organisms as rumen microorganisms mediate fiber degradation, VFA production and nutrient availability. Synbiotic supplementation probably changes microbial composition increasing total and cellulolytic bacteria, which increased feed conversion and daily gain. Therefore, we anticipate positive relationships between microbial counts (e.g., total, cellulolytic bacteria) and traits (final weight, total gain, ADG, digestibility) and negative correlations with FCR.

The positive correlations of rumen microbial communities and growth performance characteristics observed in this study also validate the significant role of rumen microbiota in increasing nutrient utilization efficacy in synbiotic-supplemented lambs. The significant relation between total and cellulolytic bacterial counts and final body weight, total gain, and average daily gain ($r=0.72-0.81$; $p<0.05$) shows that synbiotic supplementation increased the rumen fermentation efficiency and fiber digestion. This is also in agreement with the information obtained from Bettini *et al.*, and Bhogaju *et al.*, which reported that probiotics added to a rumen improved the bacterial diversity and cellulolytic activity and digestibility and performance in sheep and goats [25; 26]. Accordingly, Ban & Guan, and Wang *et al.*, showed that *Ruminococcus albus* and *Fibrobacter succinogenes* population growth also contributed to better volatile fatty acid (VFA) formation and improved feed conversion efficiency among ruminants [27; 28]. A negative and strong relationship with total bacterial count and feed conversion ratio ($r = -0.69$; $p<0.05$) is also found, indicating that high microbial biomass is associated with better nutrient degradation, and energy capture and therefore feed for equivalent unit of gain lessens. Similar results by Chen *et al.*, Li *et al.*, and Saravani *et al.*, established that dietary supplementation with multi-strain probiotics or synbiotics improved microbial protein synthesis in fattening lambs and reduced feed-to-gain ratios [29-31]. Arsène *et al.*, pointed out, however, that the size of the response is limited according to how much of the supplement, and what kind of microorganisms are present, as excess probiotic may disrupt the environment as it can disrupt the balance of microbiologically competent microorganisms on the end-to-end process with poor performance [32]. Taken together, the current results indicate that moderate synbiotic supplementation increases the growth–microbiological interactions by buffering rumen fermentation and promoting cellulolytic bacterial species responsible for the degradation of fiber. These microorganisms also are linked to increased energy supply and better growth, consistent with the mechanistic observation of Morgavi *et al.*, and Liu *et al.*, on effect of beneficial rumen microbes on nutrient turnover and fermentation balance [33; 34].

Table 6.

Correlation coefficients (r) between production traits and rumen microbial populations in Arabi lambs

Parameter	Total Bacteria ($\times 10^9$ CFU/ml)	Cellulolytic Bacteria ($\times 10^7$ CFU/ml)
Final body weight (kg)	0.72*	0.68*
Total gain (kg)	0.78**	0.73**
Average daily gain (g/day)	0.81**	0.75**
Dry matter intake (kg/day)	0.32 (NS)	0.29 (NS)
Feed conversion ratio	-0.69*	-0.63*

* $p < 0.05$; ** $p < 0.01$; NS = non-significant

Blood Metabolites

The synbiotic-supplemented groups exhibited significantly higher ($p < 0.05$) serum glucose and total protein, with lower urea and cholesterol levels compared to the control (Table 7). These results suggest improved energy metabolism, protein synthesis, and reduced nitrogen excretion. The higher glucose concentration is consistent with the elevated ruminal propionate levels, providing more precursors for gluconeogenesis. Similarly, the increase in serum protein reflects improved dietary protein utilization and hepatic synthesis. The decrease in serum urea supports efficient nitrogen retention, while the reduction in cholesterol indicates improved lipid metabolism and possibly lower oxidative stress. Similar patterns were reported by Elliethy *et al.*, and Saravani *et al.*, who observed enhanced metabolic health in lambs fed probiotics [17; 31]. Direkvandi *et al.*, also reported lower plasma urea nitrogen concentrations with microbial additives, suggesting better synchronization between energy and nitrogen availability for microbial protein synthesis [22]. The results further agree with Yue *et al.*, who concluded that synbiotics modulate ruminal microbiota, improving overall host metabolism and immunity [11].

Table 7.

Serum biochemical indices (Mean $\pm$ SE)

Parameter	Control	3 kg Synbiotic	5 kg Synbiotic
Glucose (mg/dL)	61.2 $\pm$ 1.5 ^b	70.4 $\pm$ 1.7 ^a	68.8 $\pm$ 1.6 ^{ab}
Total protein (g/dL)	6.23 $\pm$ 0.11 ^b	6.85 $\pm$ 0.13 ^a	6.74 $\pm$ 0.12 ^{ab}
Albumin (g/dL)	3.41 $\pm$ 0.09 ^a	3.52 $\pm$ 0.08 ^a	3.49 $\pm$ 0.09 ^a
Urea (mg/dL)	34.8 $\pm$ 1.2 ^a	30.2 $\pm$ 1.1 ^b	31.0 $\pm$ 1.1 ^b
Cholesterol (mg/dL)	87.4 $\pm$ 2.1 ^a	78.6 $\pm$ 1.8 ^b	80.1 $\pm$ 1.9 ^b

^{ab}Means within the same row with different superscripts differ significantly ($p < 0.05$).

Correlation of blood metabolite and rumen microbiota

The ruminant microbiota correlated with blood biochemical indices confirmed the metabolic association between the microbiota and the systemic nutrient metabolism of Arabi lambs (Table 8). Positive correlations of glucose and total protein with total and cellulolytic bacterial count indicate that increased microbial fermentation facilitated the generation of volatile fatty acid, especially propionate, the primary gluconeogenic precursor in ruminants [23].

Again, greater microbial protein synthesis most likely led to greater circulating protein content, in line with the study by Bettini *et al.*, and Mani *et al.*, who demonstrated better nitrogen retention and blood protein profiles in synbiotic-fed small ruminants [25; 35]. This inverse correlation of rumen microbial diversity with urea and cholesterol concentrations highlights that nutrients are more efficiently utilized as a substrate and lipid mobilization decreases, indicating a more advantageous energy balance and liver function in symbiotically enriched ruminants. Similar decreases in serum urea and cholesterol were also detected by Trukhachev *et al.*, and Firouzi & Haghghatdoost, after probiotic supplementation in sheep and goats [36; 37].

The weak but non-significant increase in albumin suggests stable hepatic protein turnover, implying that the improved metabolic status did not impose physiological stress on the animals. Collectively, the results show that synbiotic-induced modulation of rumen microbiota enables metabolic efficiency and thus general physiological stability in growing lambs.

Table 8.

Correlation coefficients (r) between rumen microbial populations and blood biochemical parameters in Arabi lambs

Blood Parameter	Total Bacteria ($\times 10^9$ CFU/ml)	Cellulolytic Bacteria ($\times 10^7$ CFU/ml)
Glucose (mg/dL)	0.72*	0.68*
Total Protein (g/dL)	0.66*	0.64*
Albumin (g/dL)	0.33 (NS)	0.29 (NS)
Urea (mg/dL)	-0.58*	-0.55*
Cholesterol (mg/dL)	-0.61*	-0.59*

* $p < 0.05$; NS = non-significant

Economic Efficiency

The economic evaluation showed that the synbiotic supplementation at 3 kg/ton feed resulted in 26% decrease in the feed cost/ kg gain which was higher than the control feed (Table 9). The total revenue and the net profit were

highest with the group of 3 kg/ton which had a higher profitability index of 12.8%. This improvement is due to better growth rate and feed efficiency that decreased feed cost per unit gain. Mao et al., and Saleem et al., also reported similar economic benefits with the use of probiotic and synbiotic inclusion in small ruminant production systems and emphasized the economic feasibility of microbial additives in small ruminant production systems [8; 14]. The benefit of biogenic efficiency and economic sustainability of livestock production through synbiotic supplementation is especially important for the livestock production system in the context of southern Iraq, which is a semi-arid area.

Table 9.

Economic efficiency of Arabi lambs fed synbiotic-supplemented diets

Parameter	Control	3 kg Synbiotic	5 kg Synbiotic
Feed cost (USD/kg feed)	0.35	0.36	0.36
Feed cost per kg gain (USD)	2.84	2.11	2.28
Total revenue per lamb (USD)	94.2	112.5	108.3
Net profit (USD)	23.1	38.4	33.7
Profit index (%)	100	112.8	110.4

Conclusion

The current study showed that dietary supplementation with synbiotics significantly increased growth performance and nutrient utilization of Arabi lambs raised in Basrah field conditions. Supplementation of the basal diet with 3 kg/ton and 5 kg/ton synbiotic significantly increased final body weight, average daily gain, and apparent nutrient digestibility in comparison with the untreated control group. The maximum efficiency is obtained with 3 kg/ton, which indicates a higher feed conversion efficiency and relatively more digestible dry matter, crude protein, and fiber fractions (ADF and NDF) as well as moderate feed intake levels. Such an improvement is probably linked to the synergistic effects of probiotic cultures (*Bacillus subtilis*, *Bacillus licheniformis*, and *Enterococcus faecium*) and their metabolic products, which can improve rumen microorganisms balance, enzymatic activity, and nutrient availability. Overall, moderate synbiotic addition (3 kg/ton feed) should be suggested as a feasible and environmentally friendly feeding practice for improved feed utilization and productivity of Arabi lambs without compromising intake and health status in general. The long-term effects on rumen fermentation dynamics and carcass quality in different management conditions should also be tested in more cases.

Ethics committee conclusion. The study was performed at College of Veterinary Medicine, University of Basra, with the ethical approval number (EA/VM 35/04-25-2024).

Conflict of interest information. The authors declare no conflict of interest.

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