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Methionine-Supplemented Diet Increases the General Performance and Value of Rahmani Lambs

Research Article

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ABSTRACT

Essential amino acids such as methionine have been increasingly included into diets of lambs. However, few studies have determined the effects of methionine supplementation in the general performance and economic returns of lamb production. To address this question, 21 weaned male Rahmani lambs were allotted to 3 dietary treatments: control diet (C), control diet plus 3.30 g of methionine/kg concentrate feed mixture (T1), and control diet plus 3.63 g of methionine/kg concentrate feed mixture (T2). T1-fed lambs showed significantly higher (P<0.05) total body weight gain than those fed diets C. The digestibility coefficients of dry matter (DM), organic matter (OM), crude protein (CP), ether extract, (EE), and nitrogen free extract (NFE) for T1 and T2 were significantly better (P<0.05) than for C. Economically, dietary feed T1 and T2 increased the net profit by 329.64 Egyptian pounds EGP/lamb and 305.76 EGP/lamb, respectively, as compared with the control diet. In addition, the economic efficiency (average feed cost/kg of body weight gain) was 10.02 for C and T1 and 10.48 for T2. Total costs were similar between the 3 dietary treatments. In conclusion, feeding growing Rahmani lambs with 3.30 g of methionine/kg concentrate feed mixture improved their growth performance and raised their economic value.

KEY WORDS economics, growth, methionine, Rahmani lambs.

INTRODUCTION

Feed additives such as probiotics, chelated minerals, and protected amino acids have been introduced into the market over the past years to improve the nutrient availability, utilization, and consequently, the general performance of ruminant livestock. Interest in the use of probiotics as feed supplements for ruminants has particularly increased in most recent years.

Methionine and lysine are the most limiting amino acids for ruminants because of their low concentrations in feed proteins. Indeed, methionine is the most limiting amino acid for protein synthesis in growing lambs (Storm and Orskov, 1984; Nolte *et al*. 2004) and steers (Greenwood and Titgemeyer, 2000). However, the bioavailability of methionine is limited due to its degradation in the rumen (Schwab *et al.* 2001).

Supplementing ruminant diets with ruminally undegradable proteins can increase the flow of nitrogen and amino acids to the small intestine (Titgemeyer *et al*. 1989) and result in improved growth and efficiency of nitrogen utilization (Goedeken *et al*. 1990). However, feeding ruminally undegradable proteins can decrease the efficiency of microbial protein synthesis and flow of microbial amino acids to the small intestine (Cecava *et al*. 1991) Compared with feeding more degradable protein sources. Plant proteins deficient in methionine (Schwab *et al*. 1986) and rumininat animals cannot synthesize methionine and, therefore, me-

thionine must be supplied from the dietary degradable protein and microbial protein synthesis (Lapierre *et al*. 2009).

The economic benefits of methionine feeding have been poorly studied. However, the only economic study conducted so far showed that feeding methionine to growing lambs increases the net profit by $ 6.017/lamb besides improving their growth performance (Abdelrahman and Hunaiti, 2008).

Due to inadequate methionine in plant proteins especially in feeding of growing lambs, we aimed to test the supplementation of methionine in the diet of Rahmani lambs, and study the effect of different dietary amounts of methionine on the growth performance of lambs. A detailed economic analysis was also performed.

MATERIALS AND METHODS

Animals, diets, and experimental design

Twenty-one male Rahmani lambs (31.67±0.89 kg body weight; 7 months of age) were included in a growth performance trial for 120 days at the experimental station of the Faculty of Agriculture, Damanhour University, from December 2009 to April 2010. Lambs were housed in pens with concrete floors. All lambs were vaccinated for common infectious diseases and dewormed before the experiment started.

The lambs were randomly divided into 3 groups, and each group was assigned to one of the following dietary treatments: control diet (C), control diet plus 3.30 g of methionine (free amino acid)/kg concentrate feed mixture (T1), or control diet plus 3.63 g methionine/kg concentrate feed mixture (T2).

The composition of the concentrated feed mixture was as follows: 17% undecorticated cottonseed meal, 8% soybean meal, 55% yellow corn, 17% wheat bran, 1.5% limestone, 1.4% sodium chloride, 0.1% common salt.

The essential amino acid (methionine) analysis was done with a Beckman System 7300 amino acid analyzer after 22 h of acid hydrolysis (6 N HCI) at 110̊C (AOAC, 1995). The methionine content was 520 mg/kg concentrated feed mixture.

Lambs in the growing trial were weighed in the morning before drinking or feeding at the beginning of the trial and biweekly thereafter. Concentrate feed mixtures were fed at the rate of 2.5% of body weight, while wheat straw was offered ad lib.

Concentrate feed mixtures were adjusted to changes in body weight every 2 weeks and given twice daily at 9:00 am and 1:00 pm. The offered and refused amounts were weighed daily. Drinking water was available for animals all day. Body weight changes and daily gain were recorded for each animal.

After the growth performance trial, a digestibility trial was conducted on 3 animals from each group for 14 days (preliminary period), followed by another 6 days (collection period). The animals were fed individually according to the normal allowances of the experiment assignment. During the collection period, feces were quantitatively collected from each animal. The animals were fitted with bags and harnesses for collecting feces. A plastic bag was usually inserted into the continually attached bag. Each day the plastic bag was removed with its content of the daily feces and weighed. A new plastic bag was inserted. A representative sample of feces (10%) was taken daily and deep freezed. Fecal collection durated for six consecutive days after which the daily samples belonging to the same animal were pooled together, and its moisture content was estimated at 60 ˚C for 48 h. The dried feces samples from each animal were mixed and saved for chemical analysis. Samples (concentrate feed mixture, wheat straw, and feces) were milled through a 1 mm sieve for chemical analysis. Dry matter (DM) was determined by drying the samples at 105 ˚C for six h and ash by igniting the samples in muffle furnace at 600˚C for 2 h. Organic matter (OM), ether e xtract (EE) and crude fiber (CF) following the procedure of AOAC (2005). Nitrogen free extract (NFE) was calculated as (100-(CP+EE+CF+ash)). Nitrogen (N) content was measured by the kjeldahl method. Crude protein (CP) was calculated as N (nitrogen) * 6.25. All chemical analysis was carried out in duplicate. Cell wall constituents of concentrate mixture and wheat straw were determined according to the method of (Van Soest *et al.* 1991; AOAC, 2005). Chemical analysis and cell -wall constituents are presented in Table 1.

Table 1 Chemical composition and cell wall constituents of feed concentrate mixture and wheat straw

Items	Feed concentrate mixture	Wheat straw
Chemical composition		
DM	88.97	91.36
OM	93.73	92.31
CP	15.27	2.68
CF	9.27	39.95
EE	2.37	1.77
NFE	66.82	47.91
ASH	6.27	7.69
Methionine	520	-
Cell wall constituents		
NDF	35.92	76.42
ADF	17.71	52.61
Hemi cellulose	18.21	23.81
NFC*	40.17	11.44

NFC: non fibrous carbohydrates= 100 - % (CP+NDF+EE+ASH).
DM: dry matter; OM: organic matter CP: crude protein; CF: crude fiber; EE: ether extract and NFE: nitrogen free extract.

Economic evaluation

The costs calculated herein are total variable costs (TVC), which include the feed price and feed additive costs.

Each lamb was quoted the same price and received the same labor, litter, veterinary care (drugs, vaccines, and veterinary supervision), water and electrolytes. The building and equipment depreciation value was fixed for all animals. Hence, all these parameters were considered fixed costs (total fixed costs [TFC]).

The building and equipment depreciation value was calculated considering that the building and equipment were depreciated over 25 and 5 years, respectively. Furthermore, we applied the straight-line depreciation method suggested by Sankhyan (1983) according to the following equation: ([value of building or equipment (EGP)/number of years]/[number of cycles of the project per year]/total number of animals). In addition, total costs (TC) were calculated as the sum of the TFC and the TVC.

The return items included the final body weight value, the weight gain value, and the fertilizer sale value. Total return (TR) was calculated by summation of the sales of the lambs and fertilizer. Net profit (NP) was calculated by finding the difference between the TR and the TC.

Collective and partial efficiency measures were also computed. Collective efficiency measures included percentage of net profit to variable and total costs, and percentage of total returns to variable and total costs. Partial efficiency measures included percentage of feed costs relative to total, variable costs, and total returns. Moreover, it included the percentage of total veterinary management costs relative to total costs, and the average feed cost relative to kg body weight gain.

A correlation matrix including the different production, return, and cost parameters was generated to demonstrate the degree of correlation between the investigated variables and to determine the best variables to introduce into the production and cost functions. These correlations were classified into the following groups: high positive correlation (>0.50), medium positive correlation (0.34-0.50), low positive correlation (0-0.33), high negative correlation (>-0.50), medium negative correlation (-0.34--0.50), and low negative correlation (0--0.33).

Production and cost functions were used to assess the effect of changes in production, cost parameters, and returns in lamb production using the forward, backward, enter, and mixer methods of SPSS/PC (2001).

Linear and logarithmic production functions were computed. These production functions were intended to estimate the effects of feed additives on the body weight of the lambs.

Linear and logarithmic cost functions were categorized into the following 2 models: the first one considers the effect of body weight (independent variable) on TC (dependent variable); the second model considers the effect of TR (independent variable) on TC (dependent variable).

The best computed production and cost functions exhibited the best acceptance, both economically and statistically (according to the level of significance, as determined by F-tests and *t*-tests and by the adjusted coefficient of determination R^2), and the most accurate lamb production results (El-Tahawy, 2010). The adjusted regression coefficient (R^{-2}) was used instead of the regression coefficient itself, because the number of independent variables increased such that the value of the regression coefficient increased and lost its significance.

Statistical analysis

Statistical analysis was performed using The Statistical analysis System (SAS, 2002). The differences in values were analyzed by one-way analysis of variance (ANOVA), followed by Duncan's multiple range tests.

All results are expressed as the mean ± standard error. P-values of less than 0.05 were considered statistical significant. The statistical model was represented by:

$$Y_{ij} = \mu + T_i + E_{ij}$$

Where:

Y_{ij}: represents the dependent variable.

μ: the overall mean.

T_i: the mean effect of the treatment.

E_{ij}: the random residual variation.

RESULTS AND DISCUSSION

Growth and digestibility trial

The question of supplementing the methionine in the free form rather than protected is due to supplementing ruminant diets with ruminally undegradable proteins can increase the flow of nitrogen and amino acids to the small intestine (Titgemeyer *et al*. 1989) and result in improved growth and efficiency of nitrogen utilization (Goedeken *et al*. 1990).

However, feeding ruminally undegradable proteins can decrease the efficiency of microbial protein synthesis and flow of microbial amino acids to the small intestine (Cecava *et al*. 1991) Compared with feeding more degradable protein sources. Moreover, plant proteins deficient in methionine (Schwab *et al*. 1986) and ruminanat animals cannot synthesize methionine and, therefore, methionine must be supplied from the dietary degradable protein and microbial protein synthesis (Lapierre *et al*. 2009).

The initial body weight, final body weight and total body weight gain of the lambs subjected to the growth performance experiment are listed in Table 2. The average initial body weights of lambs on diets C, T1, and T2 were 31.57 kg, 31.86 kg and 31.57 kg, respectively.

Table 2 Effect of methionine feeding on the body weights of Rahmani weaned lambs (mean±standard error)

Groups	Initial body weight (kg)	Body weight at 65 day (kg)	Final weight at 120 days (kg)	Total gain of the entire period (120 days) (kg)
Group 1 (C)	31.57±1.55[a]	41.57±1.84[a]	51.29±1.72[a]	19.71±0.52[b]
Group 2 (T1)	31.86±1.89[a]	43.43±2.02[a]	53.71±2.24[a]	21.86±0.59[a]
Group 3 (T2)	31.57±1.39[a]	42.71±1.88[a]	52.43±1.55[a]	20.86±0.40[ab]

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
Group 1: control group; Group 2: supplemented with 3.30 g of methionine/kg concentrate feed mixture and Group 3: supplemented with 3.63 g of methionine/kg concentrate feed mixture.

The final body weight of T1-fed (53.71 kg) was slightly higher (P>0.05) than that of lambs fed diets C (51.29 kg) and T2 (52.43 kg). However, the total body weight gain of T1-fed lambs was significantly higher than that of C-fed (21.86 kg versus 19.71 kg; P<0.05).

This is concordant with previously published data (Abdelrahman and Hunaiti, 2008) showing that methionine feeding at 4 g/lamb/day significantly (P<0.05) increases total gain and average daily gain of growing Awassi lambs. In the same line, Mata *et al*. (2000) reported that weight gain and wool growth of weaned Merino lambs increases (P<0.05) when lambs are fed methionine at 2.5 g/day.

Lambs fed diet T1 showed significantly higher body weight changes (178.02 g/lamb/day; P<0.05) than C-fed lambs (153.85 g/lamb/day) over the first 65 days of the experiment (Table 3).

Table 3 Body weight changes of Rahmani weaned lambs (g/lamb/day) throughout the experiment (mean±standard error)

Period	Group 1	Group 2	Group 3
0-65 days (g)	153.85± 0.004[b]	178.02± 0.007[a]	171.43± 0.009[ab]
66-120 days (g)	176.62± 0.008[b]	187.01± 0.008[a]	176.62± 0.01[b]
Entire period (0-120 days) (g)	164.29± 0.004[c]	182.14± 0.004[a]	173.81± 0.003[b]

The means within the same row with at least one common letter, do not have significant difference (P>0.05).
Group 1: control group; Group 2: supplemented with 3.30 g of methionine/kg concentrate feed mixture and Group 3: supplemented with 3.63 g of methionine/kg concentrate feed mixture.

The same trend was observed during the period from day 66 to day 120 and throughout the entire experiment. Average daily feed intakes were 925 g, 959 g, and 1009 g/lamb/d for groups C, T1, and T2, respectively (Table 4) from day 0 to day 65 of the growth trial. The average daily feed intakes during the period from day 66 to day 120 and throughout the entire experiment were similar among the 3 groups.

No significant difference in feed conversion ratio was found between diets C, T1, and T2 throughout the entire period of the experiment. The results of feed intake for different dietary treatments are presented in Table 5.

The T2 diet significantly (P<0.05) decreased dry matter (DM) intake from concentrate or roughage compared to other control. This finding is consistent with work by Abdelrahman and Hunaiti (2008), who found that 4 g of methionine/lamb/day significantly decreases total feed intake. On the other hand, the percentage of concentrate or roughage was unaffected by feed diets containing methionine. Feeding of methionine at a level of T1 and T2 significantly (P<0.05) increased the coefficients of DM, organic matter (OM), crude protein (CP), ether extract, (EE), and nitrogen free extract (NFE). However, methionine feeding had no significant effect on crude fiber digestibility. In addition, levels of methionine at T1 and T2 significantly increased the nutritive values expressed as total digestible nutrient (TDN) and digestible crude protein DCP, compared to the control.

The increase in digestibility coefficients is a good indicator of the promicrobial activity of methionine. Mardiati *et al*. (2008), Nolte and Ferreira (2005), and Adriana *et al*. (2009) have all suggested that methionine stimulates rumen microorganisms and may even be used directly by them. i.e., micro-organisms required limiting amino acid especially methionine to improve their activity in ruminal degradation of feed. Moreover, earlier work by Barakat and Saddick (1988) stated that the digestibility coefficients of DM, OM, CP, and NFE and nutritive values were improved when Ossimi lambs were fed methionine at 3.30 g/kg of dry matter feed mixture as compared to those fed a methionine-free diet.

Economic study

In this study, the TFC was 69.50 EGP per lamb. This value included the price of equipment and building depreciation (0.50 EGP and 16.00 EGP, respectively), water and electricity (2 EGP), labor (48 EGP) and veterinary management (3 EGP). As regards the TVC (Table 6), no significant differences were found among the 3 groups. Consequently, the TC of C, T1, and T2 groups were not significantly different either (961.55, 989.40 and 982 EGP/lamb/120 days, respectively). The TR values obtained in the form of fertilizer and lamb sales are shown in Table 7.

Table 4 Feed consumption (g/lamb/d) and feed conversion throughout the experimental period of the weaned Rahmani lambs (mean±standard error)

Period	Feed consumption (g/day)			Feed conversion		
	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3
0-65 days (g)	925.00±19.65[b]	959.00 ±20.79[b]	1009.00±29.13[a]	6.01±0.64[a]	5.39±0.47[a]	5.88±0.59[a]
66-120 days (g)	1249.00±35.15[a]	1304.00±43.25[a]	1254.00±32.02[a]	7.07±0.58[a]	6.97±0.46[a]	7.09±0.61[a]
Entire period (0-120 days) (g)	1074.00±30.29[a]	1117.00±49.76[a]	1120.00±38.31[a]	6.54±0.34[a]	6.13±0.44[a]	6.44±0.33[a]

The means within the same row with at least one common letter, do not have significant difference (P>0.05).

Group 1: control group; Group 2: supplemented with 3.30 g of methionine/kg concentrate feed mixture and Group 3: supplemented with 3.63 g of methionine/kg concentrate feed mixture.

Table 5 Dry matter intake and apparent digestibility and nutritive value of different experimental treatments

Items	Group 1	Group 2	Group 3
Dry matter intake			
Concentrate	865.97±23.73[a]	756.24±39.23[ab]	697.52±48.02[b]
Roughage	191.31±29.62[a]	137.24±9.17[ab]	97.82±25.43[b]
Total	1057.28±8.61[a]	893.48±46.95[b]	795.34±60.01[b]
% Concentrate	81.93±2.68[a]	84.65±0.53[a]	87.84±2.58[a]
% Roughage	18.06±2.68	15.35±0.53[a]	12.16±2.58[a]
Digestibility coefficients			
DM	68.08±1.29[b]	73.57±0.99[a]	73.76±1.46[a]
OM	70.66±1.07[b]	76.44±0.93[a]	77.20±0.99[a]
CP	71.20±0.54[b]	77.34±1.31[a]	76.60±0.50[a]
CF	53.60±0.31[a]	54.97±0.72[a]	53.91±1.41[a]
EE	72.66±1.31[b]	77.58±0.40[a]	78.29±0.93[a]
NFE	74.67±0.73[b]	79.54±0.70[a]	79.44±0.63[a]
Nutritive values			
TDN	68.21±0.46[b]	72.07±0.91[a]	72.81±0.40[a]
DCP	9.25±0.20[b]	10.31±0.13[a]	10.51±0.19[a]

The means within the same row with at least one common letter, do not have significant difference (P>0.05).

DM: dry matter; OM: organic matter; CP: crude protein; CF: crude fiber; EE: ether extract; NFE: nitrogen free extract; DCP: digestible crude protein and TDN: total digestible nutrient.

Table 6 Variable and total costs (EGP/lamb/120 days) throughout the experimental period

Group	Feed and feed additive costs (EGP)	Purchased lambs (EGP)	TVC (EGP)	TC (EGP)
Group 1	198.05±3.66[b]	694.54±52.18[a]	892.05±50.90[a]	961.55±52.60[a]
Group 2	219.55±4.18[a]	700.92±46.75[a]	919.90±43.57a	989.40±42.44[a]
Group 3	218.33±6.18[a]	694.54±61.96[a]	913.06±52.59[a]	982.56±50.41[a]

The means within the same column with at least one common letter, do not have significant difference (P>0.05).

TC: total costs; TVC: total variable costs and EGP: egyptian pounds.

Group 1: control group; Group 2: supplemented with 3.30 g of methionine/kg concentrate feed mixture and Group 3: supplemented with 3.63 g of methionine/kg concentrate feed mixture.

Table 7 Total returns parameters (EGP/lamb/120 days) throughout the experimental period

Group	Fertilizer sales (EGP)	Lamb sales (EGP)	TR (EGP)	NP (EGP)
Group 1	30.00±0.00[a]	1230.96±6.92[c]	1260.96±6.85[c]	299.41±8.13[b]
Group 2	30.00±0.00[a]	1289.04±6.64[a]	1319.04±7.33[a]	329.64±10.64[a]
Group 3	30.00±0.00[a]	1258.32±7.23[b]	1288.32±5.25[b]	305.76±6.88[b]

The means within the same column with at least one common letter, do not have significant difference (P>0.05).

TR: total returns and NP: net profit.

Group 1: control group; Group 2: supplemented with 3.30 g of methionine/kg concentrate feed mixture and Group 3: supplemented with 3.63 g of methionine/kg concentrate feed mixture.

Table 8 Collective efficiency measures

Group	NP/total costs (%)	NP/variable costs (%)	Total return/total costs (%)	Total return/variable costs (%)
Group 1	31.14±0.25[b]	33.56±0.23[b]	131.14±0.26[b]	141.36±0.31[b]
Group 2	33.32±0.24[a]	35.83±0.25[a]	133.32±0.24[a]	143.39±0.33[a]
Group 3	32.21±0.21[b]	33.49±0.24[b]	132.21±0.29[b]	141.10±0.38[b]

The means within the same column with at least one common letter, do not have significant difference (P>0.05).

NP: Net profit.

Group 1: control group; Group 2: supplemented with 3.30 g of methionine/kg concentrate feed mixture and Group 3: supplemented with 3.63 g of methionine/kg concentrate feed mixture.

Total returns of lambs fed diet T2 were significantly higher (1319.04 EGP; P<0.05) than those of lambs fed diet C (1260.96 EGP) or T2 (1288.32 EGP). The net profits of the C and T2 groups were significantly lower (299.41 EGP and 305.76 EGP, respectively; P<0.05) than of those lambs given diet T1 (329.64 EGP).

As presented in Table 8, T1-fed lambs had significantly higher efficiency measures (P<0.05) than the other groups. The percentage of net profit to TC was 33.32% for T1, whereas the percentages for the C and T2 groups were 31.14% and 32.21%, respectively. The same trend was observed for the percentages of net profit to TVC, TR to TC, and TR to TVC, i.e., T1 achieved significantly higher values than C and T2.

Partial efficiency measures are presented in Table 9. The percentages of feed costs to TC and TVC between the groups were not significantly different (P>0.05), the percentage of feed costs to TC for C, T1, and T2 being 20.60%, 22.19%, and 22.22%, respectively. The percentages of feed costs to TR were not significantly different either (P>0.05), the percentage of feed costs to TR for C, T1, and T2 being 15.71%, 16.64%, and 16.95%, respectively.

The percentage veterinary management costs to TC were 0.30% (T1) and 0.31% (C and T2).

The average feed cost relative to total gain ranged between 10.02 and 10.048 and was not significantly different among the groups.

The correlations between body weight, weight gain, feed intake, FCR, TVC, TC, and TR are shown in Table 10. A medium positive correlation was found between the initial weight and weight gain (0.601). A high positive correlation was demonstrated between weight gain and TR (0.938). A low positive correlation was found between weight gain and feed intake (0.174). Medium positive correlations were found between weight gain and both TVC (0.517) and TC (0.433). However, weight gain was negatively correlated with FCR (-0.989).

Production function

Effect of different rates of methionine feeding on Rahmani lamb body weight

Different amounts of methionine supplementation had significantly different effects (P<0.05) on Rahmani lamb body weight. Nevertheless, approximately 26% of the overall changes in body weight were attributed to methionine supplementation. From the equation described below, we found that increasing the amounts of methionine (3.30 g and 3.36 g) by approximately 1% led to body weight increases of about 0.10 and 0.12%, respectively.

Function	Log (body weight)= 0.68 + 0.10 log (3.30 g methionine) + 0.12 log (3.36 g methionine)
T	(35.89)* (42.17)* (34.73)*
F	(112.23)*
R^{-2}	0.26

* Significant at P<0.05.

Table 9 Partial efficiency measures

Group	Feed cost/total costs (%)	Feed cost/variable costs (%)	Feed cost/total returns (%)	Veterinary management/total costs (%)	Feed cost/total gain
Group 1	20.60±0.65[a]	22.20±0.55[a]	15.71±0.35[a]	0.31±0.03[a]	10.02±0.25[a]
Group 2	22.19±0.54[a]	23.87±0.65[a]	16.64 ±0.44[a]	0.30±0.03[a]	10.02±0.35[a]
Group 3	22.22±0.50[a]	23.91±0.66[a]	16.95±0.40[a]	0.31±0.03[a]	10.48±0.32[a]

The means within the same column with at least one common letter, do not have significant difference (P>0.05).

Group 1: control group; Group 2: supplemented with 3.30 g of methionine/kg concentrate feed mixture and Group 3: supplemented with 3.63 g of methionine/kg concentrate feed mixture.

Table 10 Correlation coefficients (r) between growth performance and economic parameters of the Rahmani lambs

	Initial W.T	Final W.T	W.G	Feed consumption	FC	TVC	TR
Initial W.T	-	-	-	-	-	-	-
Final W.T	0.622*	-	-	-	-	-	-
W.G	0.601*	0.858**	-	-	-	-	-
Feed consumption	0.066	0.089	0.174	-	-	-	-
FC	-0.551*	-0.812**	-0.989**	-0.032	-	-	-
TVC	0.919**	0.581*	0.517*	0.421*	-0.412*	-	-
TR	0.942**	0.960**	0.938**	0.089	-0.892**	0.681*	-
TC	0.819**	0.781**	0.433*	0.449*	-0.412*	0.870**	0.681*

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

W.G: weight gain; FC: feed conversion; TVC: total variable costs; TR: total returns and TC: total costs.

Cost and return functions

Relationship between body weight and TC of supplemented methionine at different supplementation rates

We found a significant effect (P<0.05) between body weight and TC when using diets C, T1, and T2, with about 15% of the changes in TC attributable to the change in body weight.

Increasing the body weight by approximately 1% due to methionine supplementation at different rates (3.30 and 3.36 g) led to increased TC of about 0.06% and 0.09%, respectively.

Function	Log (body weight)= 1.52 + 0.06 log (3.30 g methionine) + 0.09 log (3.36 g methionine)
T	(19.20)* (27.30)* (32.22)*
F	(100.89)*
R^{-2}	0.15

* Significant at P<0.05.

Relationship between TR and TC in diets with different amounts of supplementary methionine

A significant relationship (P<0.05) was observed between the TR and TC values when using different amounts of methionine supplementation (3.30 and 3.36 g), with about 18% of the changes in TC attributable to the change in the TR. An increased in TR by about 1% under the effects of supplemented methionine at different rates (3.30 and 3.36 g) led to TC increases of about 0.13 and 0.17%, respectively.

Function	Log (body weight)= 0.52 + 0.13 log (3.30 g methionine) + 0.17 log (3.36 g methionine)
T	(26.88)* (16.08)* (21.15)*
F	(85.62)*
R^{-2}	0.18

* Significant at P<0.05.

CONCLUSION

Supplementary feeding of methionine (3.30 g/kg concentrate feed mixture) was significantly correlated with increased body weight gain, and it exerted a positive effect on the overall performance of Rahmani lambs. Economically, it increased the net profit. Moreover, the economic efficiency (average feed cost/kg body weight gain) range was significantly improved. Based on the abovementioned advantages, we recommend the inclusion of methionine at 3.30 g of methionine/kg concentrate mixture in the dietary feed of growing Rahmani lambs.

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