Supplementation of growing male lambs rations with fumaric acid salts and its influences on ruminal fermentation and animal growth performance

Eliwa A. I., Salama R., El-sysy M., Awad A. A.[*]

Animal Production Department, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt

Abstract

Twenty four crossbred male lambs (Finn-Ossimi), were randomly assigned to four nutritional groups, to receive one of the following experimental rations for 77 days. Treatments were; T_1: 70% CFM + 30% BS, T_2: 70% CFM + 30% BS + 3% fumaric acid (FA)/roughage ratio, T_3: 70% CFM + 30% (BH) and T_4: 70% CFM + 30% BH + 3% fumaric acid (FA)/roughage ratio. Experimental rations used, based on concentrate pelleted feed mixture (CFM, 15% CP) and either bean straw (BS) or berseem hay (BH) as a daily roughage sources. The main objective of the study was to evaluate the effect of fumaric acid supplementation to growing male lambs rations on ruminal fermentation activity and lambs growth performance. Animals live body weight gain, feed intake (g/h/d) and feed conversion ratio (kg intake/kg gain) were estimated. A metabolic trial was conducted, to evaluate experimental rations digestibility, NV, NB and ruminal fermentation measurements. Results obtained indicated significant differences ($p<0.05$) in rations nutrients digestibility values. Both the two control rations within each roughage source indicated lower digestibility values in compare with the corresponding supplemented ones. Higher ($p<0.05$) nutritive values were recorded by T_3 and T_4 (BH-F groups) in different feeding terms, *i.e.* higher TDN, DCP and C/P ratio, in compare with the corresponding BS rations. Different experimental groups indicated significant NI/h/d, while both the two dietary supplemented groups recorded higher NI in compare with their corresponding control ones, however, (ND and NB), indicated insignificant differences among different experimental groups. The effect of dietary fumaric acid supplement on some ruminal measurements indicated significant differences ($p<0.05$) among different experimental groups in favor of both the two supplemented groups. Growth performance of crossbred male lambs, indicated insignificant higher daily gain for both the two BH groups in compare with the corresponding BS groups, besides higher insignificant faster daily gain values for both the two supplemented groups in compare with the corresponding control ones. FC ratio favored both the two BH groups as the more efficient feed utilizers in compare with both the corresponding two BS groups, while both the two supplemented groups surpassed insignificantly both the two control groups, within each roughage source. Results of economic efficiency indicated significant differences among different experimental groups in feed cost/kg gain, Both the two control groups recorded lower ($p<0.05$) feed costs/kg gain, while supplementing the control rations with fumaric acid led to increase ($p<0.05$) daily feed costs/kg gain and reduce ($p<0.05$) the net profit value. On the light of the present results it could be concluded that supplementing the control rations T_1 and T_2 with fumaric acid did not lead to an obvious advantages on animal performance.

Keywords: fumaric acid, been straw, berseem hay, ruminants.

*Corresponding author: Awad A. A.,
  E-mail address: ahmed.salem@azhar.edu.eg

1. Introduction

Organic acids in the rumen help to prevent the fall in ruminal pH and reducing methanogenesis. Thus, in the rumen, these acids can stimulate ruminal growth of prominent bacteria and consequently change favorably ruminal fermentation, and improve ruminant performance. Acids used as feed additives are predominantly compounds that naturally occur in cell metabolism, thus they are natural products with minimum level of toxicity. Performance and health promoting effects have been demonstrated flora number of organic acids, including citric, fumaric, formic, and lactic acid and their salts. The acids showed significant effects on feed digestion and absorption and on stabilization of rumen microflora which have been demonstrated in several studies. Carro and Ranilla (2002) showed that fumarate could beneficially affect *in vitro* rumen fermentation of concentrate feeds by increasing the production of both acetate and propionate. An increase in total VFA's concentration had basically no change in the proportion of the individual fatty acids. It seems that both acetate and propionate are formed to a same extent from disodium fumarate (DF). The possibility for both acetate and propionate formation from DF was indicated before (Ungerfeld and Kohn, 2006). The objectives of the present study was to evaluate the effect of fumaric acid supplementation to growing male lambs rations on ruminal fermentation activity, ration nutritive value and lambs growth performance.

2. Materials and methods

The present study was carried out in the agriculture research farm, belongs to Faculty of Agriculture, Al-Azhar University, Nasr City, Cairo, Egypt, in September 2018. Twenty four crossbred male lambs (Finn-Ossimi), with an average live body weight 35kg and 8 months age, were randomly assigned into four nutritional groups (6 animals each).

2.1 Experimental rations and animals management

Experimental rations used, based on concentrate pelleted feed mixture (CFM, 15% CP) and either bean straw (BS) or berseem hay (BH) as a daily roughage sources. Four experimental rations were formulated as follows:

R_1: 70% CFM + 30% BS,
R_2: 70% CFM + 30% BS + 3% fumaric acid (FA)/roughage ratio,
R_3: 70% CFM + 30% (BH),
R_4: 70% CFM + 30% BH + 3% fumaric acid (FA)/roughage ratio.

Control rations *i.e.* T_1 and T_3, were supplemented with (FA) at ratio of 3% relative to animals daily roughage intake to attain the corresponding two supplemented rations *i.e.* T_2 and T_4, respectively. Experimental animals were group feeding, offered their respective rations ad lib. according to (NRC, 2012). Daily feed residuals, if any were daily estimated. Animals were subjected to

close veterinary care , while current fresh water and salt blocks were daily available all the day time .Animals were kept in semi-opened pens during the field study which lasted for 77 days. Experimental animals were biweekly weighed to adjust their daily feed intake and fumaric acid dose supplement (g/h/day) during the field study. Animals live body weight, daily gain, feed intake (g/h/d) and feed conversion ratio (kg intake/kg gain) were estimated. Rations chemical composition, digestibility and nutritive values were also measured.

Table (1): Composition of the experimental rations percentages.

Contents	Experimental rations				Price (LE /kg) Exp. ration
	T_1	T_2	T_3	T_4	
Concentrate feed mixture (CFM)	70	70	70	70	4.80
Bean straw	30	30	--	--	2.00
Berseem hay	--	--	30	30	2.00
Fumaric acid[*]	--	3	--	3	200.00
Costs/kg DM	3.96	5.76	3.96	5.76	---

[*]Fumaric acid supplements (3% /roughage source level).

2.2 Metabolic trials

At the end of the growth performance study, a metabolic trial was conducted, using 16 adult rams (4 animals /treatment), according to El-shazly (1958). Animals' nitrogen balance (NB) was also estimated. Animals were fed the tested experimental rations for 10 days before being suited in the metabolic cages, followed by three days preliminary and adaption period and 5 days for feces and urine collection. Samples of rations offered and residuals if any were daily recorded during the collection period for further chemical analysis.

2.3 Ruminal measurements

By the end of the metabolic trials, 100ml rumen liquid samples were individually withdrawn, using rubber stomach tube technique, before feeding 0.0 time, 3 and 6 hours post feeding. Ruminal samples were strained through three layers of cheese cloth, treated with toluene and paraffin oil and were kept at -20C˚ tell later chemical analysis. Rumen fluid pH was immediately measured using Orion 680 digital pH meter, Ammonia-nitrogen concentration (NH_3-N) mg/100 ml was determined according to Conway (1963) and TVFA's were assessed by steam distillation, according to Abou-Akkada and Osman (1967).

2.4 Proximate chemicals analysis

Samples of feedstuffs ingredients, complete mixed rations, residues and feces were analyzed for moisture, crude protein (CP), ether extract (EE), crude fiber (CF), nitrogen free extract (NFE),

ash and urinary nitrogen according to AOAC (2012).

2.5 Economic efficiency

An economic study was conducted to justify average daily feed cost/h/day and the corresponding net profit value, as the difference between feed costs and the current selling market price/kg live body weight in 2018.

2.6 Statistical analysis

Data obtained were statistically analyzed as a completely randomized design by analysis of variance (ANOVA) using the statistical package software SAS version 9 (SAS Institute Inc., 2002, Cary, NC., USA). Comparisons between the treatment means were made by *F*-test and the least significant differences (LSD) at level $P = 0.05$. One way analysis of variance was adopted using the following equation:

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

Where; Y_{ij}: the observation of the parameter measured, μ: overall means, T_i: the effect of dietary treatment, R_j: the effect of replication, and E_{ij}: the random error term.

3. Results and Discussion

3.1 Chemical analysis of experimental rations

Data presented in (Table 2) showed proximate chemical analysis of the different experimental rations. As shown DM ranged between 91.8% for berseem hay (BH) rations (T_3 and T_4) to 92.11% for Bean straw (BS) rations (T_1 and T_2), respectively. Organic matter (OM) ranged between 87.31% for BS rations to 88.29% for BH ones, while CP ranged between 14.22% to 16.40% indicating higher CP value, due to berseem hay roughage as a good CP roughage source in compare with bean straw.

Table (2): Proximate chemical analysis of different experimental rations on DM basis (%).

Nutrients	CFM[1]	CFM + BS[2]	CFM + BH[3]
DM	89.68	92.11	91.81
OM	88.38	87.30	88.29
CP	15.23	14.22	16.40
CF	13.70	20.20	17.70
EE	3.08	3.77	4.26
NFE	56.37	49.12	49.93
Ash	11.62	12.69	11.71

DM = dry matter, OM = organic matter, CP = crude protein, EE = ether extract, CF = crude fiber, NFE = nitrogen free extract, [1]CFM = concentrate feed mixture, [2]BS = bean straw, [3]BH = berseem hay.

Higher CF content for bean straw rations 20.20% *vs* 17.70% for BH ; 3.77% EE for BS rations in compare with 4.26% for BH, but almost similar NFE value for both BS rations (T_1 & T_2) and berseem hay rations (T_3 and T_4) which ranged between 49.12% for the formers and 49.93% for the later ones. Ash content ranged between 11.71% for T_3 and T_4 to 12.69% for BS rations (T_1 and T_2), respectively.

3.2 Digestibility coefficients and nutritive values of the experimental rations

Data presented in Table (3) showed significant differences among different groups in daily DMI/h/d. As shown, higher ($p < 0.05$) DMI by T_4, *i.e.* 1462 g/h/d in compare with the other groups, and however T_4 BH supplemented group, surpassed the corresponding control one (T_3), T_1(control of BS) surpassed the corresponding supplemented one (T_2), *i.e.* 1452 *vs* 1440 g/h/d. Reveres results were reported by Khampa (2009) and Foley *et al.* (2009) who showed that dietary supplemented rations of lactating dairy cows with DL-Malate did not affect significantly cows feed intake. From another point of view, it was noticed that both of T_3 and T_4 (BH groups) surpassed ($p < 0.05$) the corresponding (BS groups); may be due to the higher palatability and nutritive value of berseem hay in compare with bean straw. As for digestibility coefficient of different rations, it was shown higher ($p < 0.05$) DM digestibility value for R4 (BH-supplemented with fumaric salts) in compare with the corresponding BH control group, *i.e.* 69.40 *vs* 63.64%. On the contrarily, both the two BS groups, *i.e.* T_1 and T_2 did not differ ($p < 0.05$) from each other, *i.e.* 66.41 and 66.93%, respectively. As for OM, it was shown significant differences among different experimental groups, since BH-F (T_4), recorded the higher value 73.19% and without significant difference with their control (T_3), *i.e.* 68.92% which was

higher ($p < 0.05$) than both the two BS groups (T_1 and T_2), respectively. As for CP digestibility, it was shown higher CP digestibility for both the two supplemented groups *i.e.* T_2 and T_4 in compare with the corresponding control ones *i.e.* 68.14 and 70.53 for BSF and BHF *vs* 63.51 and 66.41% for their corresponding ones. EE digestibility values, indicated ($p < 0.05$) differences among groups, however T_4, recorded the highest value (72.16%) in compare with the other groups, but without significant difference with either its corresponding control or T_2 (BS-F), while (the control BS) recorded the lowest ($p < 0.05$) value 60.13%. CF digestibility indicated ($p < 0.05$) differences among different experimental groups, however both the two BH-F groups (T_3 and T_4) recorded the higher CF digestibility values in compare with the corresponding BS groups (T_1 & T_2). Bean straw non-supplemented group recorded the lowest CF digestibility value (49.57%). As for NFE, it was shown that both the two supplemented groups with fumaric (F) surpassed ($p < 0.05$) the corresponding control ones, which showed nearly similar values, *i.e.* 74.55 and 74.46 and without significant deference between them. According to Callaway and Marten (1997) Klover *et al.* (2004) and Yu *et al.* (2010), organic acids have been recommended as one of the methods to prevent ruminal acidosis associated to high grain diets, through increasing the conversion of lactate to propionate and subsequently increasing ruminal pH and

digestibility of ruminant animals. As a general conclusion; it was noticed that, supplementing berseem hay and bean straw with fumaric acid led to improve its nutrients digestibility values in compare with their corresponding control ones, and BH groups surpassed the corresponding BS groups, may be due to the higher palatability and nutritive value of BH in compare with BS.

Table (3): Digestibility coefficients and nutritive values of the experimental rations.

Items	Experimental rations			
	T_1	T_2	T_3	T_4
Dry matter intake kg/h/d				
Total DM intake g/h/d	1452^c	1440^d	1457^b	1462^a
Digestibility coefficients (%)				
DM	66.41^{ab}±1.80	66.93^{ab}±1.21	63.64^b±0.98	69.40^a±2.11
OM	67.69^b±1.44	68.71^b±1.51	68.92^{ab}±1.01	73.19^a±1.71
CP	63.51^c±3.13	68.14^{ab}±1.53	66.41^b±1.66	70.53^a±2.90
EE	60.13^b±4.27	64.24^{ab}±3.62	61.17^{ab}±3.92	72.16^a±3.03
CF	49.57^b±4.14	50.35^b±2.64	58.85^{ab}±2.48	65.00^a±3.32
NFE	74.55^b±2.50	77.27^a±1.05	74.46^b±0.89	77.41^a±1.28
Nutritive values (%)				
TDN	62.28^b±1.45	63.36^b±1.48	63.77^{ab}±1.07	68.09^a±1.64
DCP	9.44^b±0.24	10.03^b±0.41	10.42^{ab}±0.52	11.18^a±0.25
C/P ratio	6.60^c±0.04	6.32^b±0.22	6.12^a±0.19	6.1^a±0.17

[a, b, c, d]; means with different superscripts in the same row are significantly different from each other ($p \leq 0.05$).

3.3 Experimental rations nutritive value

Nutritive values of different experimental rations differed ($p<0.05$), in different nutritional terms, and confirmed the previous observation of nutrients digestibility coefficient values. Berseem hay as a palatable legume roughage, either supplemented or non-supplemented surpassed bean straw in terms of TDN and DCP values, *i.e.* 63.77% and 68.09% TDN for T_3 and T_4 *vs* 62.28 and 63.36% for T_1 and T_2 (bean straw groups) and 10.42 & 11.18% *vs* 9.44 and 10.03% DCP values, respectively (Table 3). From an another point of view, supplementing both the two roughages with fumaric acid led to improve its nutritive values, in compare with the two non-supplemented ones, *i.e.* the two control rations, *i.e.* T_1 and T_3, respectively. Calorie/protein ratio as a nutritional measurement, indicated significant differences among different experimental rations and ranged between 6.1, 6.12 for both the two BH groups, respectively to 6.60 and 6.32 for both the two BS groups (T_1 and T_2), respectively. However, C/P ratio for different groups, irrespective of supplementation and source of roughage experienced, indicated an appropriate energy protein ratio for feeding male lambs at such age and live body weight (NRC, 2012).

Table (4): Effect of dietary fumaric acid supplements on nitrogen retention (g/h/day) of crossbred male lambs.

Items	Experimental rations			
	T_1	T_2	T_3	T_4
N intake g/h/d	$25.29^b\pm1.96$	$27.07^a\pm0.18$	$25.33^b\pm2.97$	$28.90^a\pm1.55$
Fecal N g/h/d	$7.39^b\pm0.81$	$9.10^{ab}\pm0.48$	$8.14^{ab}\pm1.18$	$10.59^a\pm1.27$
N digested g/h/d	17.90 ± 1.77	17.97 ± 0.40	17.19 ± 1.87	18.30 ± 1.14
Urinary N g/h/d	1.14 ± 0.21	0.91 ± 0.04	0.94 ± 0.40	1.00 ± 0.05
Total excreted N g/h/d	8.53	10.01	9.08	11.59
N balance g/h/d	16.76 ± 1.65	17.06 ± 0.44	16.25 ± 1.85	17.31 ± 1.11
% N balance/intake	66.10 ± 2.90	63.05 ± 1.79	64.31 ± 1.34	66.03 ± 2.94
% N balance/digested	93.69 ± 0.92	94.92 ± 0.33	94.40 ± 0.53	94.53 ± 0.27

[a, b] means with different superscripts in the same row are significantly different from each other ($p \leq 0.05$).

3.4 Effect of dietary fumaric acid supplements on nitrogen retention (g/h/d) of crossbred male lambs

Monitoring the nitrogen balance is a useful and an accurate method to justify ruminant animals performance and therefore it is used widely for this purpose. Results obtained in Table (4), pointed out to significant differences among different experimental groups in daily NI and fecal N excreted. As shown, both the two supplemented groups indicated higher N intake, *i.e.* 27.07 and 28.90 (g/h/d). This matter may be related to the biochemical influence of fumaric acid supplement on improving rations digestibility, (Table 3), irrespective of source of roughage used. In this regard, conflict results were illustrated, and while Mungi *et al.* (2012) pointed out to insignificant effect of Malate on nitrogen retention and intake on fattening lambs; Bayaru *et al.* (2001) observed greater digestibility of CP and nitrogen retention in the steers supplemented with FA in compare with the non – supplemented groups. Both the two control rations, (Table 4) *i.e.* T_1 and T_3 indicated almost similar NI/h/d, (25.29 and 25.33 g/h/d), respectively. Figures of fecal N excreted, showed a parallel and higher ($p<0.05$) fecal N excretion which coincide with the higher ($p<0.05$), N intake/h/d of each group. As shown, both the two dietary supplemented groups indicated almost similar and insignificant fecal N excreted/h/d. Such results led to almost similar and insignificant N digested/h/d. Similar and insignificant urinary N excreted was also detected for different nutritional groups, irrespective of dietary fumaric acid supplements. Such observations resulted consequently in almost similar and insignificant N balance for different experimental groups. However, both the two supplemented groups, and irrespective of dietary roughage source indicated insignificant higher N balance values, *i.e.* 17.06 and 17.31 g/h/d, for both (BS-F) and (BH-F) groups, respectively. Similar results were reported by Gonzalez-Mominta *et al.* (2009), who stated that

there were no changes observed in NB of dairy cows when sodium fumarate (SF) was add to their diets. Data of percentage of NB /intake and/or digested pointed out to insignificant differences among different nutritional groups. Data obtained in both criteria indicated almost similar insignificant values, irrespective of the significant dietary intake /h /d in different groups, either due to dietary fumaric acid supplements or source of roughage used. Such results might conclude that neither CP content of the ration (Table 1), nor its availability and digestibility or rations nutritive values, (Table 3) had significant influences on N retention/h/d under such rations formula and/or dietary organic acid supplementation.

3.5 Effect of dietary fumaric acid supplements on some ruminal measurements

3.5.1 pH

Data presented in Table (5), indicated significant differences among different groups in ruminal pH value. As shown, both of the two control groups (nil fumaric acid supplement) indicated higher ($p<0.05$), pH values, *i.e.* 7.02 and 7.03, while both the two fumaric acid supplemented groups showed lower ($p<0.05$), pH values, i.e. 6.51 and 6.89 and without significant difference between them, may be due to fumaric acid supplement as an organic acid, hence resulted in more ruminal acidity media. Similar results were reported by Callaway and Marten (1996), Lopez *et al.* (1999) and Asanuma *et al.* (1999). As for the effect of time of sampling on pH value; it was shown higher ($p<0.05$) value, before feeding, declined dramatically ($p<0.05$), to 6.36 and 5.59 after 3 and 6 hrs, respectively.

3.5.2 NH_3-N (mg /100ml)

NH_3-N indicated significant differences among different treatments. As shown, T_3 and T_4 showed higher ($p<0.05$) NH_3-N values, regardless of dietary fumaric acid supplement; both the control (nil) fumaric supplement and T_4 *i.e.* the supplemented group recorded higher ($p<0.05$) NH_3-N values, in compare with the corresponding bean straw groups, either supplemented (T_2) or non-supplemented with fumaric acid (T_1). Such results might point out that source of roughage, *i.e.* bean straw and berseem hay had a significant effect on NH_3-N concentration rather than the organic acid supplement. Both the two berseem hay recorded the higher NH_3-N values in compare with the corresponding bean straw groups. And with regard to the effect of time of sampling on NH_3-N release, it was shown higher ($p<0.05$), NH_3-N concentration 3hrs post feeding *i.e.* 11.32 mg/100ml and indicating the peak of NH3-N concentration in compare with lower ($p<0.05$) values before feeding (9.60mg/ 100ml) and declined sharply ($p<0.05$) to (7.53 mg/100ml) after 6 hrs post feeding. Similar results

238

were obtained by Bayaru, *et al.* (2001) who pointed out to (p<0.05) increase in NH3-N and TVFA's, two hrs after feeding, decreasing thereafter 6 hrs post-feeding, when supplementing rations of Holstein steers with 2% fumaric acid.

Table (5): Effect of dietary fumaric acid supplements on some ruminal measurements.

Item	Sampling time (hrs)	Experimental rations				Overall mean
		T_1	T_2	T_3	T_4	
pH	0	8.73±0.12	8.23±0.48	8.87±0.07	8.73±0.06	8.64[a]±0.13
	3	6.33±0.19	5.83±0.09	7.03±0.23	6.23±0.47	6.36[b]±0.18
	6	6.00±0.20	5.47±0.07	5.20±0.12	5.70±0.38	5.59[c]±0.13
	Overall mean	7.02[a]±0.44	6.51[b]±0.46	7.03[a]±0.54	6.89[ab]±0.50	
NH$_3$–N (mg/100ml)	0	8.28±0.23	10.85±0.35	11.08±0.84	8.17±0.31	9.60[b]±0.47
	3	10.97±0.23	8.75±0.40	11.90±0.54	13.65±0.35	11.32[a]±0.56
	6	6.77±0.23	7.82±0.82	6.77±0.23	8.75±0.40	7.53[c]±0.32
	Overall mean	8.67[b]±0.63	9.14[b]±0.53	9.92[a]±0.85	10.19[a]±0.89	
TVFA's (meq/100 ml)	0	26.67±0.83	18.33±0.83	29.17±0.83	28.33±0.07	25.63[c]±1.41
	3	41.17±0.73	38.67±0.72	41.33±0.73	45.83±0.83	41.75[a]±0.48
	6	40.00±0.57	34.17±0.83	47.55±1.44	38.67±0.73	40.08[b]±1.50
	Overall mean	30.39[c]±3.11	35.94[b]±2.35	37.61[ab]±2.64	39.33[a]±2.74	

[a, b, c] means with different superscripts in the same row or column are significantly different from each other (p≤ 0.05).

3.5.3 TVFA's (meq /100 ml)

Total volatile fatty acid concentration indicated significant differences among different groups, recording higher (p<0.05) TVFA's values with both the two berseem hay groups (T_3 and T_4). Both the two groups surpassed (p<0.05) the corresponding two bean straw groups, irrespective of dietary fumaric acid supplement. Such result might point out to an obvious influence of roughage source, rather than dietary fumaric acid supplement on TVFA's production. From an another point of view, both the two supplemented groups within both the two roughage source groups indicated higher TVFA's concentration in compare with the corresponding two controls within each roughage source, being significant (p<0.05) within BS and non-significant within BH groups. Similar results were reported by Bayaru *et al.* (2001), who revealed that the concentration of TVFA's tended to be higher for steers fed with fumaric acids throughout the sampling period. And while acetic acid was unchanged, the propionic acid was (p<0.05) increased and butyric acid was decreased. Such results might lead to a

conflict interaction between roughage source and dietary organic acid supplement on TVFA's production. Similar results were reported by Carro *et al.* (2006) on male lambs and Klover and Aspin (2006), on dairy cows, who pointed out to insignificant difference detected in daily ruminal pH, total and individual fatty acids due to supplementing pasture with sodium fumarate at 5% of DM and offered *ad lib* to dairy cows. As for the effect of time of sampling, it was shown higher ($p<0.05$) TVFA's production, 3hrs post feeding (41.75 meq/100ml) reaching to the peak of TVFA's production, declined ($p<0.05$) to 40.08 meq/100ml post feeding, while the least ($p<0.05$) TVFA's concentration was detected before feeding (25.63 meq/ml).

3.6 Effect of fumaric acid supplements on growth performance and feed conversion ratio of growing crossbred male lambs

Data in Table (6) indicated insignificant differences among different experimental groups in different growth terms, either in initial and final LBW (kg), or in total LBW gain (kg) or avg. daily LBW gain (g/h/d). However, both the two control groups indicated relatively lower insignificant final and total live body weight (kg) and also lower daily gain/h/d in grams, in compare with the corresponding supplemented groups, *i.e.* T_2 and T_4. Similar results were reported by Martin *et al.* (1999) who revealed that, supplementing finishing diets of

calves with DL-Malate improved linearly ($p<0.01$) calves ADG and gain to feed ratio by about 8.1% in compare with the corresponding control ones. From an another point of view, both the two BH groups (supplemented and non-supplemented ones), indicated relatively higher insignificant growth values in different terms, suggesting higher superiority of BH groups in compare with BS groups. Such results might be related to the higher palatability, nutritive value and digestibility coefficient values of rations of the former groups (Table 3) *i.e.* T_3 and T_4, respectively. With regard to daily feed intake (g/h/d); it was shown higher ($p<0.05$) daily intake values for BH groups *i.e.* T_3 and T_4 in compare with the corresponding two BS groups, in different feeding terms, *i.e.* DMI, TDNI and DCPI /h/d, respectively. Regarding the effect of dietary fumaric acid supplements on crossbred male lambs feed conversion ratio *i.e.* kg DMI, TDNI and kg DCPI/kg LBW gain, it was shown insignificant differences among different nutritional groups. However, both the two BH groups surpassed the corresponding two BS groups in their feed conversion ratio and being more efficient ones in converting DM, TDN and DCP intakes to live body weight gain. Results of FC ratio confirmed the previous trends, since both the two BH groups, irrespective of FA supplements surpassed the corresponding two BS groups. Moreover, both the two dietary supplemented groups surpassed insignificantly the corresponding two

240

control groups. Similar results were reported by Mungoi *et al.* (2012), Remling *et al.* (2014) using fumaric acid, Ebrahim *et al.* (2015) using anthraquinone in combination with both malic and fumaric acids to evaluate the effect of such dietary organic acids supplements on lambs growth performance. They pointed out to insignificant effects to such additives on lambs ADG, FC ratio or energy per gain ratio.

Table (6): Effect of fumaric acid supplements on growth performance and feed conversion ratio of growing crossbred male lambs.

Items	Experimental rations			
	T_1	T_2	T_3	T_4
Initial body wt. (kg)	34.50±0.87	35.25±1.18	34.53±2.62	34.75±1.65
Final body wt. (kg)	50.10±1.05	51.55±0.88	51.85±4.19	53.33±2.43
Total body gain (kg)	15.60±1.11	16.30±0.51	17.33±1.60	18.58±0.79
Daily gain (g)	202.60±14.43	211.69±6.58	225.00±20.76	241.24±10.31
Growth rate (%)*	45.22[b]±3.98	46.24[ab]±2.84	50.19[ab]±1.28	53.47[a]±0.57
Daily feed intake (g/h/d)				
DM intake	1452[c]	1440[d]	1457[b]	1462[a]
% DMI / Control	100	99.17	100.34	100.68
TDNI	622.75[b]±14.53	633.63[b]±14.78	637.72[ab]±10.68	680.98[a]±16.43
DCPI	94.44[b]±2.37	100.30[b]±4.13	104.22[ab]±5.14	111.82[a]±2.51
Feed conversion ± SE (Kg intake /kg gain)				
DMI / kg gain	7.30±0.59	6.82±0.22	6.65±0.62	6.10±0.29
% Kg DMI / kg gain / cont	100	93.42	91.09	83.56
TDNI / Kg gain	3.07±0.19	2.99±0.14	2.83±0.28	2.82±0.11
DCPI / Kg gain	0.47±0.04	0.47±0.03	0.46±0.05	0.46±0.02

[a, b] means with different superscripts in the same row are significantly different from each other (p≤ 0.05), *growth rate % = Total body gain/ Initial LBW × 100.

Table (7): Effect of fumaric acid supplement on economical efficiency of growing lambs.

Items	T_1	T_2	T_3	T_4
FC (DMI / kg gain)	7.30±0.59	6.83±0.22	6.65±0.62	6.10±0.29
T. LBW gain (Kg)	15.60	16.30	17.33	18.58
Feed cost / Kg gain (LE)	28.79[b] ±2.33	39.30[a] ±1.25	26.32[b] ±2.46	35.12[a] ±1.64
Total feed costs / T.gain (LE)	442.74[d] ±0.04	638.67[b] ±0.03	444.27[c] ±0.04	648.43[a] ±0.03
Net profit (L.E)/ / kg gain	36.12[a] ±2.33	25.70[b] ±1.25	38.68[a] ±2.46	29.88[b] ±1.64
T. Net profit (L.E) / group	571.26[ab] ±72.23	420.83[b] ±32.93	681.86[a] ±103.91	558.95a[b] ±51.62

[a, b] means with different superscripts in the same row are significantly different from each other (p≤ 0.05). Current selling market price of LBW (kg) = 65 L£ at 2018.

3.7 Effect of dietary fumaric acid supplement on economic efficiency of growing male lambs

Results obtained in Table (7) indicated insignificant difference among crossbred growing male lambs in FC ratio as (kg DMI/kg gain). Feed cost/ kg gain indicated significant differences ($p<0.05$), being significantly higher for both the two FA supplemented groups, *i.e.* T_2 and T_4, mainly due to the higher cost of kg FA (Table 1). However, feed costs /kg gain showed variable significant differences, mainly due to variable insignificant differences among different groups in efficiency of male lambs feed utilization. Hence, the net profit value/group indicated significant values, being higher ($p<0.05$) with the lower feed cost /kg gain, of the two control groups. *i.e.* T_1 and T_3 and vice versa for the corresponding of higher feed costs groups, *i.e.* the two dietary supplemented groups, *i.e.* T_2 and T_4, respectively.

References

AOAC (2012), *Official methods of analysis association of official analytical chemists*, International 19th Edition, The Association of Official Analytical Chemists, Washington, D.C., USA.

Abou-Akkada, A. R. and Osman, H. E. (1967), "Studies on the utilization of non protein nitrogen in Egypt", *Journal of Agricultural Science*, Vol. 169, pp. 25–33.

Asanuma, N., Iwamoto, M. and Hino, T. (1999), "Effect of the addition of fumarate on methane production by ruminal micro-organisms *in vitro*", *Journal of Dairy Science*, Vol. 82, pp. 780–787.

Bayaru, E., Kanda, S., Kamada T., Itabashi, H., Andoh, S., Nishida, T., Ishida, M., Itoh, T., Nagara, K. and Isobe. Y. (2001), "Effect of fumaric acid on methane production, rumen fermentation and digestibility of cattle fed roughage alone", *Animal Science Journal*, Vol. 72 No. 2, pp. 139–146.

Callaway, T. R. and Martin, S. A. (1996), "Effects of organic acid and monensin treatment on *in vitro* mixed ruminal microorganism fermentation of cracked corn", *Animal Science Journal*, Vol. 74, pp. 1982–1989

Callaway, T. R. and Martin, S. A. (1997), "Effects of cellobiose and monensin on *in vitro* fermentation of organic acids by mixed ruminal bacteria", *Journal of Dairy Science*, Vol. 80, pp. 1126–1135.

Carro, M. D. and Ranilla, M. J. (2002), "los aditivos antibióticos promotores del crecimiento de los animales: Situación actual y posibles alternativas", *Revista Argentina de Producción Animal*, Vol. 238, pp. 35–45.

Carro, M. D., Ranilla, M. J., Giráldez, F.

J. and Mantecón, A. R. (2006), "Effects of malate on diet digestibility, microbial protein synthesis, plasma metabolites, and performance of growing lambs fed a high-concentrate diet", *Journal of Animal Science*, Vol. 84, pp. 405–410.

Conway, W. J. (1963), *Microdiffusion analysis and volumetric error*, Crosby Lockwood & Son. London, England, pp. 90–101.

Duncan, D. B. (1955), "Multiple Range and Multiple F Test", *Biometrics*, Vol. 11, pp. 1–24.

Ebrahimi, S. H., Datta, M. M., Heidarian, V., SIrohi, S. K. and Tyagi, A. K. (2015), "Effects of fumaric or malic acid and 9, 10 anthraquinone on digestibility, microbial protein synthesis, methane emission and performance of growing calves", *Indian Journal of Animal Sciences*, Vol. 85 No. 9, pp. 1000–1005

El-Shazly, K. (1958), "Studies on the nutritive value of some common Egyptian feedingstuffs. I. Nitrogen retention and ruminal ammonia curves", *The Journal of Agricultural Science*, Vol. 51 No. 2, pp. 149–156.

Foley, P. A., Kenny, D. A., Lovett, D. K., Callan, J. J., Boland, T. M. and Mara, F. P. O. (2009), "Effect of DL-malic acid supplementation on feed intake, methane emissions, and performance of lactating dairy cows at pasture", *Journal of Dairy Science*, Vol. 92, pp. 3258–3264.

Gonzalez-Momita, M. L., Kawas, J. R., García-Castillo, R., Gonzalez-Morteo, C., Aguirre-Ortega, J., Hernandez–Vidal, G., Fimbres-Durazo, H., Picón-Rubio, F. J. and Lu C. D. (2009), "Nutrient intake, digestibility, mastication and ruminal fermentation of Pelibuey lambs fed finishing diets with ionophore (monensin or lasalocid) and sodium malate", *Small Ruminant Research*, Vol. 83, pp. 1–6.

Khampa, S. (2009), "Effects of malate level and cassava hay in high-quality feed block on rumen ecology and digestibility of nutrients in lactating dairy cows raised under tropical condition", *International Journal of Livestock Production*, Vol. 1, No. 1, pp. 6–11.

Kolver, E. S., Aspin, P. W., Jarvis, G. N., Elborough, K. M. and Roche, J. R.. (2004), "Fumarate reduces methane production from pasture fermented in continuous culture", *New Zealand Society of Animal Production*, Vol. 64, pp. 155–159.

Kolver, E. S. and Aspin, P. W. (2006), "Supplemental fumarate did not influence milksolids or methane production from dairy cows fed high quality pasture", *New Zealand Society of Animal Production*, Vol. 66, pp. 409–415.

Lopez, S., Valdes, C., Newbold, C. J. and Wallace, R. J. (1999), "Influence of sodium fumarate addition on rumen fermentation in vitro", *British*

Journal of Nutrition, Vol. 81, pp. 59–64.

Martin, S. A., Streeter, M. N., Nisbet, D. J., Hill, G. M. and Williams, S. E. (1999), "Effects of DL-malate on ruminal metabolism and performance of cattle fed a high-concentrate diet", *Journal of Animal Sciences*, Vol. 77, pp. 1008–1015.

Mungói, M., Flores, C., Casals, R. and Cajab, G. (2012), "Effect of malate and starch source on digestibility and nutrient balance of growing-fattening lambs", *Animal Feed Science and Technology*, Vol, 174, pp. 154–162.

NRC, (2012), *Nutrient requirements of goats: Angora, dairy, and meat goats in temperate and tropical countries*, 15 Ed., National Academy Press, Washington, D.C., USA.

Remling, N., Riede, S., Lebzien, P., Meyer, U., Höltershinken, M., Kersten, S., Breves, G., Flachowsky, G. and Dänicke, S. (2014), "Effects of fumaric acid on rumen fermentation, milk composition and metabolic parameters in lactating cows", *Journal of Animal Physiology and Animal Nutrition*, Vol. 98, pp. 968–981.

SAS (2002), *SAS/STAT User's Guide*. Version 8, 6th Edition, Statistical Analysis System (SAS) Institute, Cary, USA.

Ungerfeld, E. M. and Kohn, R. A. (2006), "The role of thermodynamics in the control of ruminal fermentation", In: *Ruminant physiology*, Wageningen Academic Publishers, Wageningen, the Netherlands, pp. 55–85.

Yu, C. W., Chen, Y. S., Cheng, Y. H., Cheng, Y. S., Yang, C. M. J. and Chang, C. T. (2010), "Effects of fumarate on ruminal ammonia accumulation and fiber digestion *in vitro* and nutrient utilization in dairy does", *Journal of Dairy Science*, Vol. 93, pp. 701–710.