Small Ruminant Research 82 (2009) 13–17

Contents lists available at ScienceDirect

Small Ruminant Research

journal homepage: www.elsevier.com/locate/smallrumres

Effects of feeding sesame meal on growth performance, nutrient digestibility, and carcass characteristics of Awassi lambs

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ARTICLE INFO

Article history:
Received 18 September 2008
Received in revised form 17 December 2008
Accepted 6 January 2009
Available online 3 February 2009

Keywords:
Awassi lambs
Sesame meal
Growth
Digestibility
Carcass characteristics

ABSTRACT

Nutrient intake, diet digestibility, N balance, carcass characteristics, and meat quality were evaluated in Awassi lambs fed different levels of sesame meal (SM). Twenty-seven Awassi lambs of similar weight (BW = 18.8 ± 0.74 kg) and age (65 ± 1.09 days) were equally divided into three treatments and fed individually high concentrate diets for 60 days. Group one served as a control and did not receive SM (SM0). Group two (SM8) and three (SM16) received 8 and 16% SM, respectively. Intakes of dry matter (DM), organic matter (OM), and crude protein (CP) were highest ($P < 0.05$) for the lambs fed the SM8 followed by the SM0 and SM16 diets, respectively. Whereas, intake of ether extracts (EE) was greater for SM16 followed by the SM8 and SM0. Intake of metabolizable energy (ME) was greater ($P < 0.05$) for SM8 than SM0 and SM16 treatments. Final weight and average daily gain (ADG) were greater ($P < 0.05$) for SM8 than for both the SM0 and SM16 diets. All groups had similar feed conversion ratio; nevertheless production cost was lower ($P < 0.05$) for SM8 and SM16 compared to SM0 diet. Digestibility of DM, OM, CP, and EE and N retention were similar among all treatment diets. Fasting live weight was greater ($P < 0.05$) for lambs fed SM8 diet than for lambs fed SM0 and SM16 diets. Dressing percentage was greater ($P < 0.05$) for SM0 diet when compared to SM8 and SM16 diets. Lungs and trachea weights were higher ($P < 0.05$) in lambs fed SM8 diet than SM0 and SM16 diets. Loin weight was greater ($P < 0.05$) in lambs fed SM8 diet compared to SM0 and SM16 diets. Lambs receiving the SM8 and SM16 diets had greater ($P < 0.05$) total percentage in loin than the SM0 diet. No differences were observed in carcass and longissimus muscle linear dimensions, fat measurements, and meat quality characteristics among the treatment diets. It is concluded that sesame meal could replace 8% of soybean meal in the diet without any detrimental effect on lamb growth and meat quality, thus reduces feeding cost.

1. Introduction

Growing Awassi lambs has been one of the most profitable sectors of raising sheep in Jordan. The increase in feed prices and the scarcity of grains and protein plant supplements are important constrains hampering sheep production sector in Jordan and in many other countries. Consequently, red meat prices have increased more than 40% and thus the profit margin stagnated for most producers. However, the total return from growing Awassi lambs has declined dramatically since the high prices of red meat scaled down the consumer demand. Therefore, keeping the production cost down is the main objective of farmers to maximize their net revenue. The agro-industrial by-products, such as sesame meal (SM), can have a major influence on reducing the production cost.

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doi:10.1016/j.smallrumres.2009.01.002

Sesame meal is a by-product of the sesame seed industry for oil extraction. In Jordan, a total of 3250 tons of sesame hulls and sesame meal are produced annually (Ministry of Agriculture, 2007). Crude protein content of sesame meal is around 46% (dry matter (DM) basis) (Ministry of Agriculture, 2007), and therefore it can be used as a protein supplement typically to replace soybean meal in feeding sheep. Thus, inclusion of sesame meal in feeding sheep will partially help producers alleviate the effect of the global rise in feed cost. Few studies have evaluated the effect of using sesame meal in sheep feeding. Omar (2002) reported that sesame meal addition at 10 and 20% improved average daily gain (ADG), feed conversion ratio, and cost of feed/kg gain in growing lambs when compared with diets did not contain sesame meal. Omar (2002) found that sesame meal addition enhanced the digestibility of both crude protein and fibre. Similarly, sesame meal (i.e., sesame oil cake) improved intake, digestibility, and growth performance when incorporated into diets for steers and growing calves (Little et al., 1991; Khan et al., 1998; Ryu et al., 1998). Little attention has been paid on the use of sesame meal in sheep feeding. Therefore, the objective of this study was to evaluate the effect of replacing soybean meal by sesame meal on feed intake, diet digestibility, average daily gain, carcass characteristics and meat quality of growing Awassi lambs.

2. Materials and methods

2.1. Design, animals and diets

Twenty-seven Awassi lambs (BW = 18.8 ± 0.74 kg) were housed individually (1.5 m × 0.75 m) and assigned randomly into one of three dietary groups containing no sesame meal (SM0; n = 9), 8% sesame meal (SM8; n = 9), and 16% sesame meal (SM16; n = 9). Diets were formulated to be isonitrogenous as shown in Table 1. Diets were offered twice a day (two equal meals at 09:00 and 16:00). The study lasted for 60 days. Sesame meal was obtained from a local seed Industry Company for oil extraction. Before mixing the diets, sesame meal was sun dried for approximately 2 days to ease the mixing process. Diets were mixed biweekly during the study and were sampled upon mixing to ensure consistency in their chemical composition. One-week adaptation period was allowed prior to recording the data during which the lambs received diets at maintenance level. Over the course of the study a total mixed ration diet was offered *ad libitum* to all animals with free access to fresh water. Refusals were weighed before the distribution of morning meal in the following day is feeding to evaluate daily DM intake and other nutrient intakes, and representative samples were taken for laboratory analysis. Feeders were managed to allow no more than 10% of feed per animal to remain 1 h prior to the following day feeding. When feeders were found empty, the amount of feed offered was scaled up by 10% on the following day. Lambs were weighed at the beginning of the study and weekly, thereafter, before the morning feeding.

At the end of the period, six animals from each treatment were selected randomly and housed individually in metabolism crates to evaluate nutrient digestibility and N balance. Animals were allowed a period of 7 days to adapt the metabolism crates, and then followed by a collection period of 4 days. Daily fecal output was collected, weighed, and recorded, and then 10% was kept for subsequent analyses. All samples were dried at 55 °C in a forced-air oven to reach a constant weight, air equilibrated, and then ground to pass 1 mm screen (Brabender OHG Duisdurg, Kulturstrase 51–55, type 880845, Nr 958084, Germany) and kept for further analysis. Feed, refusals, and feces were analyzed for DM, ash, crude protein (CP), and ether extracts (EE). Following AOAC (1990) procedures, samples were analyzed for DM (100 °C in air-forced oven for 24 h; method 967.03), ash (550 °C in ashing furnace for 6 h; method 942), CP (Kjeldahl procedure) and EE (Soxtec procedure, SXTEC SYSTEM HT 1043 Extraction Unit, TECATOR, Box 70, Hoganas, Sweden). For feeds, neutral detergent fibre (NDF) and acid detergent fibre (ADF) were analyzed according to procedures described by Van Soest et al. (1991) with modifications for use in the ANKOM^{200} fibre analyzer apparatus (ANKOM Technology Cooperation, Fairport, NY). Neutral detergent fibre analyses were conducted with using sodium sulfite and alpha amylase (heat stable) and expressed with residual ash content.

Table 1
Ingredients and chemical composition of diets fed to Awassi lambs.

Item	Diets			Sesame meal
	SM0	SM8	SM16	
Ingredients (%DM)				
Barley	45	45	45	
Soybean meal	16	8	0	
Sesame meal	0	8	16	
Wheat bran	16	16	16	
Wheat hay	20	20	20	
Salt	1.5	1.5	1.5	
Limestone	1.4	1.4	1.4	
Mineral and vitamins[a]	0.1	0.1	0.1	
Feed cost/ton (US$)	372	333	295	
Nutrients				
Dry matter (%)	91.3	90.5	90.8	92.8
Organic matter (%DM)	90.2	91.7	91.5	93.6
Crude protein (%DM)	16.3	16.5	16.4	46.0
Ether extract (%DM)	3.8	4.9	6.6	11.7
Neutral detergent fibre (%DM)	31.2	30.5	30.2	15.8
Acid detergent fibre (%DM)	17.1	16.5	16.4	8.5
Metabolizable energy (Mcal/kg)[b]	2.7	2.8	2.9	2.95

[a] Composition per 1 kg contained (vitamin A, 450,000 IU; vitamin D3, 1,100,000 IU; vitamin E, 3.18 g, Mn, 10.9 g; I, 1.09 g; Zn, 22.73 g; Fe, 22.73 g; Cu, 2.73 g; Co, 0.635; Mg, 100 g; Se, 0.1 g).
[b] Metabolizable energy: calculated using NRC (1985).

2.2. Slaughtering procedures and meat quality evaluation

At the end of the experiment (60 days) all animals (n = 26) were slaughtered to evaluate carcass characteristics and meat quality. All animals were processed by trained personnel using standard slaughter procedures (Abdullah et al., 1998) after being fasted for around 18 h. Fasted live weight was recorded immediately before slaughter, and hot carcass weight was recorded after slaughter. Cold carcass weight was recorded after carcasses were chilled at 4 °C for 24 h. Live and carcass weights were weighed to the nearest of ±0.25 kg. Dressing percentage was calculated as the percentage of hot carcass weight/fasted live weight. Non-carcass edible components were removed and weighed directly after slaughter. Non-carcass components included lungs and trachea, heart, liver, spleen, kidneys, kidney fat, mesenteric fat, and testes. On the next day, the following linear dimensions were taken (to the nearest of ±0.1 mm) on the chilled carcasses and longissimus muscle: tissue depth (GR), rib fat depth (J), eye muscle width (A), eye muscle depth (B), eye muscle area, fat depth (C), and shoulder fat depth (S2) following the procedure described by Abdullah et al. (1998). Carcasses were then cut into four parts (shoulder, rack, loin and leg cuts). Upon cutting, loin cut was dissected and longissimus muscle excised from the loin cut and vacuum-packed immediately and stored at −20 °C for 2 weeks until the time of meat quality assessment.

Meat quality parameters measured were pH, color (CIE $L^*a^*b^*$ coordinates), cooking loss, water holding capacity (WHC), and shear force values. Frozen longissimus muscles were thawed in a chiller at 4 °C over night while still in plastic bags. Each muscle was divided into slices of specific thickness and each slice was used for specified meat quality measurement as described by Abdullah and Musallam (2007) and Obeidat et al. (2008). Color was measured on slices of 15 mm thick, all slices were placed on a polystyrene tray and covered with permeable film and allowed to oxygenate for 2 h at 4 °C. Cooking loss was measured on duplicate-slices of 25 mm thickness, slices were weighed before cooking, placed in plastic bags and cooked in water bath at 75 °C for 90 min and re-weighed after cooking to calculate the percentage of water lost on cooking. The cooked slices were stored at 4 °C over night, then 6 cores, with the size of 1-mm^3 were cut from the slices to measure shear force values. Cooked meat cores were sheared in a perpendicular direction of muscle fibre using Warner–Bratzler (WB) shear blade with the triangular slot cutting edge mounted on Salter Model 235 (Warner–Bratzler meat shear, G-R Manufacturing Co. 1317 Collins LN, Manhattan, KA 66502, USA) to determine the peak force (kg) required to shear the cores. pH was measured after thawing by homogenizing 2 g of raw meat in 10 ml of neutralized 5-mM iodoacetate reagent, pH of the homogenate was measured using pH spear (pH spear, large screen, waterproof pH/temperature tester, double injection, model 35634-40, Eurotech instruments, Malaysia). Water holding capacity was measured using the procedure described by Grau and Hamm (1953); approximately 5 g of raw meat was cut into small pieces and placed between two filter paper and two quartz plates, and pressed with a weight of 2500 g for 5 min, then meat was removed and weighed, WHC was calculated as a percent of the initial weight WHC% = (initial wt. − final wt.) × 100/initial wt.

2.3. Statistical analysis

Data were analyzed using MIXED procedure of SAS (Version 8.1, 2000, SAS Inst. Inc., Cary, NC). For all data, the fixed effects included only treatment. Initial body weight, live weight, and carcasses measurements were used as covariant for analysis. Least square means were separated using appropriate pair-wise *t*-tests if the fixed effects were significant ($P < 0.05$).

3. Results and discussion

3.1. Diets, nutrient intakes, digestibility and N balance, live weight gain, and feed conversion ratio

During the second week of the study, one lamb from SM8 group was removed due to health problems not related to the study. The approximate analysis of the sesame meal is reported in Table 1 reveals how fine and rich sesame meal is when used as a feed ingredient to replace soybean meal; the most expensive ingredient in diets of growing lambs and livestock. Authors did not pay attention to the EE changes when replacing soybean meal by sesame meal in SM8 and SM16 diets when compared to the control diet (i.e., SM0). The reason behind that was to keep all other ingredients fixed and therefore to evaluate the effect of replacing soybean meal by sesame meal only. Nutrient composition of the three diets was similar except for the EE content due to the high level of EE in the sesame meal when compared to the soybean meal. Little et al. (1991) and Sauvant et al. (2004) reported the crude protein content in the sesame meal was 46 and 45%, respectively, which is similar to the crude protein used in the current study. However, Khan et al. (1998) and Omar (2002) reported lower levels of the crude protein (i.e., 22.7 and 32.1%, respectively). The reason for this disagreement could be related to the oil extraction method. Therefore, it should be analyzed to ensure the nutrient content.

Nutrient intake and growth performance results of Awassi lambs fed different levels of sesame meal are presented in Table 2. Lambs fed the SM8 diet had higher ($P < 0.05$) intakes of DM, organic matter (OM), and CP compared to lambs fed SM0 or SM16 diets. Whereas, intake of EE was highest for SM16 followed by the SM8 and SM0. Metabolizable energy intake was greater ($P < 0.05$) for lambs fed SM8 than SM0 and SM16 treatments. Similarly, previous work showed that using sesame meal in feeding growing bull calves has increased their nutrient intake (Khan et al., 1998). However, Omar (2002) reported that DM intake decreased numerically when sesame meal was fed to lambs at levels of 10 and 20%. Omar (2002) reported greater fat intake in diets that contained sesame meal. This higher intake of the SM8 dietary group could be related to the fact that feeding two different protein sources (i.e., soybean meal and sesame meal) could change the amino acid profile in the diet, which means that the proteins would complement each other. This suggests that the presence of SM in lambs' diet did not affect the palatability when the inclusion rate was up to 8%.

Table 2
Nutrient intake and growth performance of Awassi lambs fed diets containing sesame meal.

Item	Diets			S.E.
	SM0	SM8	SM16	
Nutrients intake				
Dry matter (g/d)	933^b	1025^a	835^c	30.9
Organic matter (g/d)	844^b	944^a	771^c	28.1
Crude protein (g/d)	150^b	167^a	135^c	5.1
Ether extract (g/d)	36^c	50^b	55^a	1.5
Metabolizable energy (Mcal/d)	2.52^b	2.87^a	2.42^b	0.09
Initial body weight (kg)	19.2	18.8	18.5	0.74
Final body weight (kg)	31.0^b	33.5^a	30.6^b	0.79
Average daily gain (g)	202.2^b	243.7^a	196.0^b	15.62
Feed conversion ratio	4.84	4.24	4.34	0.29
Cost/kg gain (US$)	1.80^a	1.41^b	1.28^b	0.104

Within a row, means without a common transcript letters (a, b and c) differ ($P < 0.05$).

Initial and final body weights, ADG, feed conversion ratio, and cost of gain are also summarized in Table 2. At the beginning of the study, average initial body weight was similar among the treatment groups. However, final weight and ADG was greater ($P < 0.05$) for lambs fed the SM8 than for both the SM0 and SM16 diets. Consistent with current study, Omar (2002) reported that ADG were greater in lambs fed sesame meal when compared to lambs fed diets contained no sesame meal. Similarly, Little et al. (1991) noted an increase of the daily gain of N'Dama bull calves supplemented with sesame meal when compared to calves supplemented with cottonseed. In the current study, the differences in ADG were mainly related to the increase in DM intake in lambs fed the SM8 diet.

In 2002, Omar reported that the sesame meal addition reduced cost of feed/kg gain in growing Awassi lambs when compared to a commercially fed ration. The results reported in the herein study are in complete harmony to Omar's finding in 2002. Although all the experimental groups showed similar feed conversion ratio the cost of production was lower ($P < 0.05$) in lambs fed on SM8 and SM16 diets compared to SM0 fed lambs. The price of soybean meal was sixfold higher compared to sesame meal price. At the time of running this experiment, the price difference between the two meals was ($500/ton). Therefore, when soybean meal was replaced by sesame meal at 8 and 16% the cost was reduced by 10 and 20%, respectively; thus, soybean meal substitution with sesame meal reduced the cost of diets and improved profitability.

Digestibility of DM, OM, CP, and EE were similar among all treatment diets (Table 3). The digestibility

Table 3
Nutrient digestibility and N balance of Awassi ram lambs fed diets containing sesame meal.

Item	Diets			S.E.
	SM0	SM8	SM16	
Digestibility (%)				
Dry matter	74.0	77.1	73.4	2.11
Organic matter	75.5	78.6	75.3	2.01
Crude protein	77.4	77.5	76.9	2.17
Ether extract	67.1	67.9	79.0	5.54
N				
Intake (g/d)	28.6^b	32.9^a	28.4^b	1.44
Fecal (g/d)	6.4	7.5	6.5	0.74
Urinary (g/d)	12.8	12.4	9.5	2.02
Retained (g/d)	9.4	13.0	12.4	1.96
Retention (%N intake)	32.3	39.4	43.5	6.46

Within a row, means without a common transcript letters (a and b) differ ($P<0.05$).

results of the current study are inconsistent with results reported by other authors (Hossain et al., 1989; Khan et al., 1998; Omar, 2002) who reported that inclusion of sesame meal improved nutrient digestibility. These differences in digestibility could be related to differences in animal species, level and nutrient content of the sesame meal, and the diet composition. N intake was greater ($P<0.05$) for lambs fed SM8 (32.9 g/d) than for lambs fed SM0 and SM16 (28.6 and 28.4 g/d, respectively). No differences were detected in fecal N, urinary N, and N retention. All animals had positive N balance. Nutrient intake and digestibility and growth performance data derived from the current study showed the possibility of replacing soybean meal partially and/or completely with enhancing the profitability.

3.2. *Carcass and non-carcass characteristics and meat quality*

To our knowledge there are no literature data on the carcass characteristics and meat quality of lambs fed sesame meal. Therefore, the discussion in this study relies on other alternative feed resources and previous work on diets containing alternative feeds.

Fasting live weight, hot and cold carcass weights, dressing percentages, non-carcass components and carcass cuts weights are shown in Table 4. No differences were observed among treatment diets with respect to the parameters except for the fasting live weight, dressing percentages, liver weight, and lungs and trachea weight. Fasting live weight was greater ($P<0.05$) for lambs fed SM8 diet than in lambs fed SM0 and SM16 diets. Dressing percentage was greater ($P<0.05$) in lambs fed SM0 diet when compared to lambs fed SM8 and SM16 diets. Lungs and trachea weights was higher ($P<0.05$) in lambs fed SM8 diet than SM0 and SM16 diets. Lambs receiving the SM8 had greater ($P<0.05$) total weight of non-carcass components when compared to the SM) and SM16 diets. Similar results were obtained on previous studies conducted on Awassi lambs fed on high concentrate diets (Abdullah and Awawdeh, 2004; Abdullah and Musallam, 2007).

Table 4
Carcass and non-carcass components of Awassi lambs fed diets containing sesame meal.

Item	Diets			S.E.
	SM0	SM8	SM16	
Fasting live weight (kg)	30.0^b	33.0^a	29.4^b	0.9
Hot carcass weight (kg)	15.4	15.4	14.1	0.5
Cold carcass weight (kg)	14.8	14.6	13.3	0.5
Dressing percentage	51.3^a	46.7^b	48.0^b	1.1
Non-carcass components (g)				
Heart weight	130	128	125	5
Liver weight	444^b	526^a	459^b	19
Spleen weight	57	61	55	2
Kidney weight	87	94	82	4
Kidney fat weight	122	124	127	15
Mesenteric fat weight	179	263	224	36
Testes weight	78	71	59	8
Lungs and trachea weight	422^b	501^a	412^b	20
Total weight	1519^b	1769^a	1544^b	63
Carcass cut weights (kg)				
Shoulders weight	5.5	5.5	5.1	0.2
Racks weight	1.3	1.3	1.2	0.1
Loins weight	1.5	1.6	1.4	0.1
Legs weight	5.0	5.1	4.7	0.2

Within a row, means without a common transcript letters (a and b) differ ($P<0.05$).

No differences were observed for dissected loins and legs except for loin weight and total fat (%) in loin (Table 5). Loin weight was greater ($P<0.05$) in lambs fed SM8 diet compared to SM0 and SM16 diets. Total lean percentage in loin was greater ($P<0.05$) for lambs fed SM8 and SM16 diets compared to SM0 diet.

Carcass linear dimensions are presented in Table 6. No differences were observed in carcass and longissimus muscle linear dimensions and fat measurements among the treatment diets. Least square means for average of meat quality characteristics measured in longissimus muscle

Table 5
Dissected loins and legs carcass cuts weights and percentages of Awassi lambs fed diets containing sesame meal.

Item	Diets			S.E.
	SM0	SM8	SM16	
Loin weight (g)	788^a	801^a	695^b	34.0
Longissimus muscle (g)	211	224	206	8
Intermuscular fat (%)	17.5	19.5	17.0	1.6
Subcutaneous fat (%)	3.8	2.8	3.1	0.4
Total fat (%)	21.3	22.4	20.1	1.7
Total lean (%)	49.8^b	53.0^a	53.2^a	1.0
Total bone (%)	23.6	19.9	22.7	1.8
Meat to bone ratio	2.17	2.52	2.85	0.20
Meat to fat ratio	2.43	2.52	2.85	0.25
Leg weight (g)	2479	2390	2348	96
Intermuscular fat (%)	2.8	2.9	3.1	0.14
Subcutaneous fat (%)	14.0	15.3	13.3	1.4
Total fat (%)	16.7	18.2	16.4	1.4
Total lean (%)	57.4	61.6	57.5	2.2
Total bone (%)	21.3	23.4	21.5	0.8
Meat to bone ratio	2.70	2.64	2.69	0.07
Meat to fat ratio	3.48	3.62	3.54	0.20

Within a row, means without a common transcript letters (a and b) differ ($P<0.05$).

Table 6
Carcass and *M. longissimus* linear dimensions and fat measurements of Awassi lambs fed diets containing sesame meal.

Item	Diets			S.E.
	SM0	SM8	SM16	
Tissue depth (GR) (mm)	9.6	11.4	10.6	0.8
Rib fat depth (*J*) (mm)	4.3	4.8	4.6	0.6
Eye muscle width (*A*) (mm)	56.7	58.1	56.4	1.1
Eye muscle depth (*B*) (mm)	25.9	25.1	24.6	0.7
Eye muscle area (cm^2)	4.1	4.2	4.1	0.2
Fat depth (*C*) (mm)	3.1	2.3	2.2	0.4
Shoulder fat depth (S2) (mm)	3.6	4.7	3.9	0.7

Table 7
Meat quality characteristics of Awassi lambs fed finishing diets containing sesame meal.

Item	Diets			S.E.
	SM0	SM8	SM16	
Ultimate pH[a]	6.16	6.15	6.10	0.04
Cooking loss (%)	41.8	42.3	41.8	1.0
Water holding capacity (%)	28.0	29.9	27.6	1.3
Shear force (kg/cm^2)	2.3	2.2	2.3	0.1
Color coordinates				
L^* (brightness)	37.80	36.89	35.38	1.4
a^* (redness)	1.99	1.75	1.18	0.3
b^* (yellowness)	17.05	18.64	17.71	1.0

[a] pH measured after thawing.

are presented in Table 7. No differences were observed between treatment diets in pH, cooking loss, water holding capacity, and shear force values. No differences were observed in brightness (L^*), redness (a^*), and yellowness (b^*).

Overall, the purpose of using alternative feedstuffs in livestock diets is to reduce the cost while improving or at least not affecting carcass characteristics and meat quality. Along with current study, using alternative feeds did not impact the carcass characteristics. For example, Lanza et al. (2003) studied the effect of feeding peas for lambs and found the meat quality (i.e., ultimate pH, meat color, and cooking loss) to be similar to lambs fed diets containing soybean meal. Lanza et al. (2001) demonstrated that inclusion 10% orange pulp and carob pulp did not impact carcass characteristics. Previous studies and the current study have shown the possibility of using alternative or unconventional feedstuffs without causing problems to carcass characteristics and meat quality.

4. Conclusion

The results of the current study showed that sesame meal is a good source of protein and may be used up to 8% without causing any deleterious effect on performance of Awassi lambs fed concentrate diets. The use of sesame meal reduced feed cost and therefore it can be used to improve profitability.

Acknowledgements

The authors wish to thank the Deanship of Scientific Research at Jordan University of Science and Technology for the financial support of this project (#156/2007). Appreciation is expressed to M. Abu-Ishmais, Rasha I. Qudsieh and Rabah Athamneh for assistance in conducting this experiment and laboratory analyses. Appreciation is also expressed to I. Tahat and farm staff at the Centre for Agriculture and Production at Jordan University of Science and Technology.

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