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Nutritional impact of partial or complete replacement of soybean meal by sesame (*Sesamum indicum*) meal in lambs rations

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Abstract

Background: One of the important by-products is sesame seed meal; it is a by-product of sesame seed pressing. Sesame oil cake or meal is a relatively good source of crude protein which can replace part of basic ingredients in diets such as soybean.

Method: Fifteen growing male Barki lambs aged 5–6 months (18.50 ± 0.98 kg) were used to investigate the influence of replacing soybean meal (SBM) that incorporated (16% of control ration) sesame meal (SM) at 50% or 100% on feed and water intakes, nutrient digestibility, growth performance, rumen parameters, and economic evaluation. Lambs received one of the three tested complete feed mixtures that contained 16% SBM (R_1), replaced 50% of SBM with SM (R_2), contained (8% SBM + 8% SM) or completely replaced 100% of SBM with SM (R_3) and contained 16% SM.

Results: Dietary treatments had no significant effect on all nutrient digestibility and total digestible nutrients value, meanwhile it decreased ($P < 0.05$) their contents of digestable crud protine when SBM was completely replaced by SM. Average daily gain (ADG) increased ($P < 0.05$) while increasing the level of replacement SBM by SM. Feed conversion expressed as g. gain improved ($P < 0.05$) with the increasing level of inclusion SM in the rations. Ruminal pH values increased ($P < 0.05$), meanwhile, values of NH_3-N concentration insignificantly decreased; however, values of total volatile fatty acid concentration insignificantly increased when SBM was replaced at half or completely by SM. Economical efficiency improved by 147.9% and 163.5% for R_2 and R_3 compared to control (R_1).

Conclusion: It can be mentioned that SM is a good source of protein and can be successfully used as an unconventional source in growing lamb rations without causing any deleterious effect on their performance, digestibility, and ruminal fermentation while realizing a decrease in feed cost with improving economic efficiency, so it can incorporate SM in sheep rations to improve profitability or net revenue and decrease feed cost/kg gain.

Keywords: Sesame seed meal, Lambs digestibility, Performance, Water intake, Ruminal fluid parameters, Economic evaluation

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Background

The feedstuff market is suffering from price fluctuations and quite often availability problems (Stillman et al. 2009; Lawrence et al. 2010; Nikolakakis et al. 2014). These detrimental situations are usually observed for high-protein feed such as soybean meal (Indexmundi 2016a), but they can also be observed for cereals such as maize (Indexmundi 2016b), barley (Indexmundi 2016c), and other feed ingredients. Consequently, farmers have problems with supplying their livestock with good quality feed, while keeping the feed cost at manageable levels. Accordingly, nowadays there is an observed increasing demand for novel feedstuffs characterized by low price and decent availability, which can be utilized in livestock feed, without any adverse effect on animal health and productivity. Therefore, many by-products of the food and feed industries are now being examined as alternative feedstuffs (Bonos et al. 2017).

According to data for FAO (2014), sesame seed production occupied 78 million acres, with a production of 3.84 million tons. The sesame seeds contain on average 44–58% oil, 18–25% crude protein, 13.5% carbohydrates, and 5% ash (Yoshida et al. 1995; Mohammed and Awatif 1998; Kahyaoglu and Kaya 2006; Elleuch et al. 2007).

The chemical composition of sesame seed meal varies according to the method of processing mechanical or solvent extraction. Dry matter (DM) contents of sesame seed meal ranged from 83 to 96% while CP, ash, ether extract, nitrogen-free extract (NFE), and crud fiber contents ranged from 23 to 46%, 7.5 to 17%, 1.4 to 27%, 25 to 32%, and 5 to 12%, respectively, as recorded by (FAO 1990; Hejazi and Abo Omar 2009; Mulugeta and Gebrehiwot 2013; Mahmoud and Bendary 2014).

Inclusion of sesame seed meal in calve rations had positive effects on its performance as noted by Ryu et al. (1998a). Also, Obeidat et al. (2009) found that when soybean meal was replaced by sesame meal (46% CP, DM basis), finishing performance improved and cost of production diminished without any detrimental effect on carcass characteristics or meat quality of Awassi lambs. Also, Abo Omar (2002) reported that the sesame oil cake addition at 10% and 20% improved growth performance (ADG: DMI, and cost of feed/kg gain) of lambs.

So, this work aimed to study the impact of partial or complete replacement of soybean meal by sesame seed meal in growing Barkki lamb rations on their growth performance, digestion coefficients, water intake, ruminal fermentation, and economic evaluation.

Methods

The present study was carried out at the Sheep and Goats Units in El-Nubaria Experimental and Production Station at El-Imam Malik Village, which belongs to the Animal Production Department, National Research Centre, Dokki, Cairo, Egypt.

Animals and feed

Fifteen growing male Barki lambs aged 5–6 months (18.50 ± 0.98 kg) were used to investigate the influence of replacing soybean meal (SBM) that was incorporated at 16% of control ration by sesame meal (SM) at 50% or 100% (equal to 0%, 8% and 16% of total ration contents) on feed and water intakes, nutrient digestibility, growth performance, some rumen fluid parameters and economic evaluation. The animals were randomly assigned to three experimental groups (five lambs in each treatment).

Experimental animals were housed in semi-open pens and fed as group feeding for 91 days and the experimental rations received would cover the requirements of total digestible nutrients and protein for growing sheep according to the NRC (1985).

R_1: First (1*st*) complete feed mixture expressed as control ration contained 16% soybean meal.
R_2: Second (2*nd*) complete feed mixture replaced 50% of soybean meal (SBM) by sesame meal (SM) (8% SBM + 8% SM).
R_3: Third (3*rd*) complete feed mixture completely replaced 100% of SBM by SM (16% SM).

Daily amounts of complete feed mixtures (CFM) were adjusted every 2 weeks according to body weight changes. Rations were offered twice daily in two equal portions at 800 and 1400 h, while feed residues were daily collected, sun dried, and weekly weighed. Fresh water was freely available at all times in plastic containers. Individual body weight change was weekly recorded before the morning meal.

Digestibility trials

At the end of the feeding trial, four animals from each group were housed in individual metabolic cages to calculate both digestibility coefficients and nutritive values.

A different tested CFM was offered at 8.00 a.m. and water was available at all times.

The digestibility trial continued for 14 days as a preliminary period followed by 7 days for feces only collection.

During the collection period, feces were quantitatively collected from each animal once a day at 7.00 a.m. before feeding. Actual quantity of feed intake consumption was recorded. A sample of 10% of the collected feces from each animal was sprayed with 10% sulphoric acid and 10% formaldehyde solutions and dried at 60 °C for 48 h. Samples were mixed and stored for chemical

Table 1 Chemical analysis and cell wall constituents of different ingredients used in ration formulation

Item	Yellow corn	Soybean meal	Sesame meal	Berseem hay	Wheat bran
Moisture	9.36	7.03	9.83	9.90	9.52
Chemical analysis (%) on DM basis					
Organic matter (OM)	98.31	95.79	91.79	91.00	88.02
Crude protein (CP)	9.05	44.00	36.12	15.50	13.91
Crude fiber (CF)	4.23	4.86	3.28	26.15	10.36
Ether extract (EE)	4.21	0.65	5.43	2.95	2.66
Nitrogen-free extract (NFE)	80.82	46.28	46.96	46.40	61.09
Ash	1.69	4.21	8.21	9.00	11.98
Cell wall constituents					
Neutral detergent fiber (NDF)	35.11	34.72	39.35	51.33	44.21
Acid detergent fiber (ADF)	20.34	24.18	25.41	30.16	31.88
Acid detergent lignin (ADL)	2.20	3.36	3.82	4.92	3.65
Hemicellulose	14.77	10.54	13.94	21.17	12.33
Cellulose	18.14	20.82	21.59	25.24	28.23
Non-fibrous carbohydrates (NFC)	49.94	16.42	10.89	21.22	27.24
Gross energy (kcal/kg DM)	4437	4669	4636	4164	4001
Digestible energy (kcal/kg DM)	3372	3548	3523	3165	3041

analysis. Composite samples of feed and feces were finely ground prior to analysis.

The nutritive values expressed as the total digestible nutrient (TDN) and digestible crude protein (DCP) of the experimental rations was calculated by classical method that was described by Abou-Raya (1967).

Rumen fluid parameters

Rumen fluid samples were collected from all animals at the end of the digestibility trial at 3 h post feeding via stomach tube and strained through four layers of cheesecloth. Samples were separated into two portions, the first portion was used for immediate determination of ruminal pH and ammonia nitrogen concentration, while the second portion was stored at − 20 °C after adding a few drops of toluene and a thin layer of paraffin oil till analyzed of total volatile fatty acids (TVFAs).

Analytical procedures

Chemical analysis of ingredients, CFM, and feces samples were analyzed according to AOAC (2005) methods.

Ruminal pH was immediately determined using a digital pH meter. Ruminal ammonia nitrogen (NH_3-N) concentrations were determined applying NH_3 diffusion technique using Kjeldahle distillation method according to AOAC (2005). Meanwhile, ruminal TVFA concentrations were determined by steam distillation according to Warner (1964).

Gross energy (Kcal/Kg DM) calculated according to Blaxter (1968). Each g CP = 5.65 Kcal, g EE = 9.40 Kcal, and g CF and NFE = 4.15 Kcal.

Digestible energy (DE) was calculated according to NRC (1977) by applying the following equation: DE (kcal/kg DM) = GE × 0.76.

Non-fibrous carbohydrates (NFC) were calculated according to Calsamiglia et al. (1995) using the following equation: NFC = 100 − {CP + EE + Ash + NDF}.

Neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were also determined according to Goering and Van Soest (1970) and Van Soest et al. (1991). Meanwhile, hemicellulose and cellulose content were calculated as follows:

$$\text{Hemicellulose} = \text{NDF} - \text{ADF}.$$

$$\text{Cellulose} = \text{ADF} - \text{ADL}.$$

Economic evaluation

Calculation of economical efficiency of tested complete feed mixtures that was used in the present work depended on both local market price of ingredients and price of sheep live body weight.

Statistical analysis

Collected data on the initial and final live body weight, total body weight gain, average daily gain, feed and water intake, feed conversion, and ruminal fermentation were subjected to statistical analysis as one way analysis of variance according to SPSS (2008). Duncan's Multiple Range test (Duncan 1955) was used to separate means when the dietary treatment effect was significant according to the following model: $Y_{ij} = \mu + T_i + e_{ij}$:

Table 2 Composition and chemical analysis of rations used in lamb feeding

Item	(R_1)	(R_2)	(R_3)	Price, L.E/Ton of ingredients
Yellow corn	40.00	34.00	28.00	3000
Soybean meal	16.00	8.00	–	6250
Sesame meal	–	8.00	16.00	3125
Berseem hay	24.00	30.00	36.00	1500
Wheat bran	17.00	17.00	17.00	2500
Limestone	1.50	1.50	1.50	100
Vit. & Min. Mixture[1]	1.00	1.00	1.00	10,000
Sodium chloride	0.50	0.50	0.50	750
Price, L.E/Ton	3090	2750	2420	
Chemical analysis				
Moisture	8.95	9.21	9.46	
Chemical analysis (%) on DM basis				
Organic matter (OM)	91.54	90.78	90.03	
Crude protein (CP)	16.74	16.50	16.25	
Crude fiber (CF)	10.51	11.70	12.87	
Ether extract (EE)	2.94	3.25	3.56	
Nitrogen-free extract (NFE)	61.35	59.33	57.35	
Ash	8.46	9.22	9.97	
Cell wall constituents				
Neutral detergent fiber (NDF)	39.44	40.79	42.13	
Acid detergent fiber (ADF)	24.67	25.35	26.05	
Acid detergent lignin (ADL)	3.22	3.43	3.62	
Hemicellulose	14.77	15.44	16.08	
Cellulose	21.45	21.92	22.43	
Non-fibrous carbohydrates (NFC)	32.42	30.24	28.09	
Gross energy (kcal/kg DM)	4204	4185	4167	
Digestible energy (kcal/kg DM)	3195	3181	3167	

R_1 Control ration contained 16% soybean meal (SBM)
R_2 Replaced 50% of soybean meal (SBM) by sesame meal (SM)
R_3 Replaced 100% of soybean meal (SBM) by sesame meal (SM)
NFC Non-fibrous carbohydrates = 100 – {CP + EE + Ash + NDF} (Calsamiglia et al. 1995) NFC = 100 – {CP + EE + Ash + NDF}
Gross energy (kcal/kg DM) was calculated according to Blaxter (1968). Each g CP = 5.65 kcal, g EE = 9.40 kcal, and g (CF & NFE) = 4.15 kcal
DE (Kcal/kg DM) = GE × 0.76 (NRC 1977)

where Y_{ij} = observation; μ = overall mean; T_i = effect of experimental rations for $i = 1–3$, 1 = R_1 contained 16% soybean meal and considered the control, 2 = R_2 replaced 50% of soybean meal in the control ration by sesame meal, and 3 = R_3 complete replacement (100%) of soybean meal in the control ration by sesame meal; and e_{ij} = the experimental error.

Results

Illustrated data in Table 1 shows that sesame meal (SM) considered a good source of protein (36.12%) that equals 82.09% of the portion of protein that found in soybean meal (SBM, 44%). However, SSM was superior in their contents of EE, hemicellulose, and cellulose (5.43, 13.94, and 21.59%, respectively) in comparison with the SBM that contained 0.65, 10.54, and 20.82%, respectively, of the same nutrients mentioned above.

Partial and complete replacement of SBM by SM (50 and 100%, respectively) lead to a decrease in the total price (L.E/ton) by 11.00% and 21.68% for R_2 and R_3, respectively, in comparison with the control (Table 2).

Inclusion SM in tested ration realized a slight decrease in the contents of CP and NFE that ranged from 16.74 to 16.25% for CP and 61.35 to 57.35%, respectively. Also, NFC, GE, and DE contents were also decreased (Table 2).

Meanwhile, an increase in their contents of CF, EE, and ash ranged from 10.51 to 12.87%, 2.94 to 3.56%, and 8.46 to 9.97%, respectively. NDF, ADF, ADL, hemicellulose, and cellulose also increased by incorporation of SM in rations.

Table 3 Digestion coefficients and nutritive values of the experimental groups

Item	R_1	R_2	R_3	SEM
Nutrient digestibility				
Dry matter (DM)	85.12	84.89	84.22	0.37
Organic matter (OM)	87.17	86.35	86.21	0.29
Crude protein (CP)	70.07	69.88	69.60	0.20
Crude fiber (CF)	67.90	68.75	68.90	0.35
Ether extract (EE)	80.76	81.38	82.16	0.30
Nitrogen-free extract (NFE)	78.09	78.02	77.99	0.27
Nutritive values (%)				
Total digestible nutrient (TDN)	72.12	71.81	71.49	0.20
Digestible crude protein (DCP)	11.73[a]	11.53[ab]	11.31[b]	0.08

[a, b]In the same row having different superscripts differ significantly ($P < 0.05$).
SEM standard error of mean.
R_1 Control ration contained 16% soybean meal (SBM).
R_2 Replaced 50% of soybean meal (SBM) by sesame meal (SM).
R_3 Replaced 100% of soybean meal (SBM) by sesame meal (SM).

Digetibility and nutritive values

Dietary treatments had no significant effect on all digestibility and TDN value (Table 3). The DCP was significantly ($P < 0.05$) reduced in R3 while the DCP in the control (R1) and R2 was similar ($P > 0.05$).

Productive performance

Dietary treatment increased ($P < 0.05$) total body weight gain and average daily gain. Both total body weight gain and average daily gain increased ($P < 0.05$) while increasing the level of replacement of soybean meal by sesame seed meal (Table 4).

Incorporation of sesame seed meal in sheep rations had no significant effect ($P > 0.05$) on all feed intake determined (g/h/day, g/kg$W^{0.75}$, and Kg/100 kg live body weight of dry matter, crude protein, digestible crude protein, non-fibrous carbohydrates and total digestible nutrients intake or expressed as kcal/h/day, kcal/kg$W^{0.75}$ and Mcal/ 100 kg live body weight of gross and digestible energy) (Table 4).

Feed conversion expressed as gram intake/gram gain of dry matter, crude protein, digestible crude protein, non-fibrous carbohydrates, and total digestible nutrient or that expressed as kilocalorie intake/gram gain of gross, and digestible energy were improved ($P < 0.05$) with increasing level of replacement of soybean meal by sesame meal (Table 4).

Drinking water

Water consumption was not significantly ($P > 0.05$) affected by the dietary treatment (Table 5).

Ruminal fluid parameters

Replacement soybean meal (SBM) by sesame meal (SM) increased ($P < 0.05$) the ruminal pH values from 5.60 in control (R_1) to 5.98 and 6.05 in R_2 and R_3, respectively, (Table 6). On the other hand, the NH_3-N and TVFAs were not affected ($P > 0.05$) by the dietary treatment.

Economic evaluation

The economic evaluation of the experimental groups is shown in Table 7. Daily profit above feeding cost was gradually increased in lambs fed R_2 (7.371 LE) and (8.150 LE) R_3 compared to R_1 (4.984 LE) as a result of increasing ADG.

Feed cost (LE per kilogram gain) was depressed by 27.47% and 38.44% for R_2 and R_3, respectively, compared to control (R_1). In addition, relative economical efficiency improved for R_2 (147.9%), and 163.5% for R_3 in comparison with control (R_1).

Discussion

Chemical composition of sesame meal varies according to the method of processing (FAO 1990; Ryu et al. 1998b; Abo Omar 2002; Hejazy 2008; Hejazi and Abo Omar 2009; Mulugeta and Gebrehiwot 2013; Mahmoud and Bendary 2014; Mahmoud and Ghoneem 2014).Variations in chemical composition of different tested rations related to different portions of ingredients used in ration formulation and also related to differences in their chemical analysis.

Results concerning the digestibility and the nutritive values are in harmony with those obtained by Ahmed and Abdalla (2005) who noticed that replacing 50% of cotton seed cake by sesame seed cake in yearling sheep had no effect on digestibility and TDN value. Also, the present results in harmony with those noted by Mahmoud and Ghoneem (2014) who noted that there were no significant ($p > 0.05$) difference in the digestibility of DM, CF, NFE, NDF, cellulose, and hemicellulose among rations that contained 50% *Nigella sataiva* meal, 50% sesame seed meal, or 25% *Nigella sataiva* meal + 25% sesame seed meal, in comparison with the control. While there were insignificant decreases in digestibility of OM, CP, and ADF for lactating buffaloes that received 50% *Nigella sataiva* meal or 50% sesame seed meal. However, the previous values decreased ($P < 0.05$) for lactating buffaloes fed 25% *Nigella sataiva* meal + 25% sesame seed meal containing rations. Also, Mahmoud and Ghoneem (2014) noted that buffaloes which received concentrate feed mixture contained 50% sesame meal insignificantly decreased DCP content comparing with those fed control ration. On the other hand, Fitwi and Tadesse (2013) noticed that feeding growing sheep diets containing 0, 150, 200, 250, and 300 g day^{-1} feed ingredient did not affect DM, OM, CP, and CF

Table 4 Productive performance of the experimental groups

Item	R_1	R_2	R_3	SEM
Live body weight (LBW), g				
Lambs number	5	5	5	–
Initial weight (IW, kg)	18.75	18.50	18.25	0.98
Final weight (FW, kg)	30.75	33.75	34.25	1.34
Total body weight gain (TBWG, kg)	12.00^{b}	15.25^{a}	16.00^{a}	0.73
Experimental duration period		91 days		
Average daily gain (ADG, g/day)	132^{b}	168^{a}	176^{a}	7.95
Total body weight gain (TBWG), kg*	24.75	26.13	26.25	1.11
Metabolic body weight (kgW$^{0.75}$) Feed intake (FI)	11.10	11.56	11.60	0.36
Dry matter intake (DMI) as				
g/h/day	865	894	902	31.26
g/kgW$^{0.75}$	77.93	77.34	77.76	2.71
Kg/ 100 kg LBW	3.50	3.42	3.44	0.12
Crude protein intake (CP) as				
g/h/day	144.8	147.5	146.6	5.12
g/kgW$^{0.75}$	13.05	12.76	12.64	0.44
g/ 100 kg LBW	585	565	558	20.15
Digestible crude protein (DCP) as				
g/h/day	101.5	103.1	102.0	3.57
g/kgW$^{0.75}$	9.14	8.92	8.79	0.31
g/ 100 kg LBW	410	395	389	13.97
Non-fibrous carbohydrates intake (NFC) as				
g/h/day	280.4	270.3	253.4	9.84
g/kgW$^{0.75}$	25.26	23.38	21.84	0.90
Kg/ 100 kg LBW	1.13	1.04	0.97	0.07
Gross energy (GE) intake as				
kcal/h/day	3636	3741	3759	13.03
kcal/kgW$^{0.75}$	327.6	323.6	324.1	11.37
Mcal/ 100 kg LBW	14.69	14.32	14.32	0.51
Digestible energy intake (DE) as				
kcal/h/day	2764	2844	2857	99.13
kcal/kgW$^{0.75}$	249.0	246.0	246.3	8.64
Mcal/ 100 kg LBW	11.17	10.89	10.88	0.38
Total digestible nutrient intake (TDN) as				
g/h/day	623.8	642.0	644.8	22.38
g/kgW$^{0.75}$	56.20	55.54	55.59	1.95
kg/ 100 kg LBW	2.520	2.457	2.456	0.09
Feed conversion expressed (FC) as g intake / g gain of				
Dry matter (DM)	6.55^{b}	5.32^{a}	5.13^{a}	0.261
Crude protein (CP)	1.10^{b}	0.88^{a}	0.83^{a}	0.045
Digestible crude protein (DCP)	0.77^{b}	0.61^{a}	0.58^{a}	0.031
Non-fibrous carbohydrates (NFC)	2.12^{b}	1.61^{a}	1.44^{a}	0.099
Total digestible nutrient (TDN)	4.73^{b}	3.82^{a}	3.66^{a}	0.191
Feed conversion expressed as kcal intake / g gain of				

Table 4 Productive performance of the experimental groups *(Continued)*

Item	R_1	R_2	R_3	SEM
Gross energy (GE)	27.55[b]	22.27[a]	21.36[a]	1.109
Digestible energy (DE)	20.94[b]	16.93[a]	16.23[a]	0.844

[a, b]In the same row having different superscripts differ significantly ($P < 0.05$).
SEM Standard error of mean.
R_1 Control ration contained 16% soybean meal (SBM).
R_2 Replaced 50% of soybean meal (SBM) by sesame meal (SM).
R_3 Replaced 100% of soybean meal (SBM) by sesame meal (SM).

digestibility of rations and in their TDN. Also, digestibility of DM was not affected by the inclusion of sesame oil cake in Awassi lamb diets as reported by Abo Omar (2002). In addition, similar results were observed in bull calves when fed rations containing sesame oil cake as noted by (Khan et al. 1998) and in goats as reported by (Hossain et al. 1989). Meanwhile, CP and crude fiber digestibility was highest ($P < 0.05$) for the diet containing 20% sesame oil cake (Abo Omar 2002). On the other hand, Yasser et al. (2015) reported that apparent digestibility of all nutrients OM, CP, CF, EE, and NFE all were increased ($P < 0.05$) with sesame seed meals in rabbits compared with the control diet.

Our results of growth performance that is published in Table 4 were in agreement with Abo Omar (2002) who showed that the average weight of Awassi lambs was higher for lambs fed 20% sesame oil cake containing ration in comparison with the control group and lambs that received 10% sesame oil cake containing ration, while the average daily gain in the 10 and 20% sesame oil cake groups was higher ($P < 0.05$) than in the control group. Moreover, Hassan et al. (2013) concluded that incorporation of sesame cake up to 20% in Sudan desert sheep rations caused satisfactory feedlot performance. Treatment had no effect ($P < 0.05$) on TDN, and that may be related to the DMI and digestibility of all nutrients which was not affected ($P < 0.05$) by treatment.

Table 5 Water consumption of the experimental groups

Item	R_1	R_2	R_3	SEM
Animal no.	5	5	5	–
Average body weight, kg	24.75	26.13	26.25	1.11
Metabolic body weight ($kgW^{0.75}$)	11.10	11.56	11.60	0.36
Dry matter intake (DMI), g	865	894	902	31.26
Drinking water expressed as				
ml/h/day	2833	3000	3250	334.5
ml/$kgW^{0.75}$	255	260	280	29.03
L/ 100 kg LBW	11.45	11.48	12.38	1.30
L/ kg DM intake	3.28	3.36	3.60	0.38

SEM Standard error of mean.
R_1 Control ration contained 16% soybean meal (SBM).
R_2 Replaced 50% of soybean meal (SBM) by sesame meal (SM).
R_3 Replaced 100% of soybean meal (SBM) by sesame meal (SM).

Dry matter and the other nutrient intake insignificantly reduced when sesame oil cake incorporated in Awassi lamb rations at 0, 10, and 20% of ration formula. These reductions in dry matter intake were recorded by 4 and 2% for lambs consuming rations containing 10 and 20% sesame oil cake, respectively, compared with the control (Abo Omar 2002). A similar trend was observed in protein intake. However, intake of fiber and fat increased ($P < 0.05$) by feeding sesame oil cake. On the other hand, the DM intake and other nutrients were similar to intake observed in many fattening studies utilizing different types of diets (Hammad 2001).

Abo Omar (2002) found that feed conversion ratio were improved ($P < 0.05$) when sesame oil cake was introduced in Awassi lamb rations at 10 and 20% of ration formula. Also, the improvement of feed efficiency was in agreement with previous work with broilers and layers fed sesame seed cake (Jacob et al. 1996). On the other hand, these findings were in accordance to Lutfi (1983), Hassan (2005), Suliman and Babiker (2007), and Hassan et al. (2013) who reported significant differences in feed conversion for sheep that received sesame cake meal up to 20%.

Increasing water intake in R_2 and R_3 compared R_1 may be due to different percent of berseem hay (R_1 24%, R_2 30%, and R_3 36%) or, may be related to the increased percentage of ash, CF, and EE contents in R_2 (9.22%, 11.70%, and 3.25%, respectively) and R_3 (9.97%, 12.87% and 3.56%, respectively) compared to control that contained ash 8.46%, CF 10.51%, and EE 2.94% as presented in Table 2. DMI and water intake are positively associated (NRC 1996), so ash is not the only constituent of dry matter in the feed, therefore, the ash contents could

Table 6 Ruminal fluid parameters of the experimental groups

Item	R_1	R_2	R_3	SEM
pH	5.60[b]	5.98[a]	6.05[a]	0.081
NH_3-N (mg/dl) concentration	34.40	33.60	33.10	1.116
TVFA (meq/dl) concentration	29.25	31.00	32.75	0.718

[a, b]In the same row having different superscripts differ significantly ($P < 0.05$).
SEM Standard error of mean.
NH_3-N Ammonia nitrogen concentrations
TVFs Total volatile fatty acid concentrations
R_1 Control ration contained 16% soybean meal (SBM).
R_2 Replaced 50% of soybean meal (SBM) by sesame meal (SM).
R_3 Replaced 100% of soybean meal (SBM) by sesame meal (SM).

Table 7 Economic evaluation of the experimental groups

Item	R_1	R_2	R_3
Daily feed intake (fresh, kg)	0.95	0.99	1.00
Price of 1 kg of CFM	3.09	2.75	2.42
Daily feeding cost (LE)[a]	2.94	2.71	2.41
Average daily gain (kg)	0.13	0.17	0.18
Value of daily gain (LE)[b]	7.92	10.08	10.56
Daily profit above feeding cost (LE)	4.99	7.37	8.15
Relative economical efficiency[c]	100	147.9	163.5
Feed cost (LE/kg gain)	22.24	16.13	13.69

LE Egyptian pound equal to 0.06 USD approximately
[a]Based on prices of year 2018
[b]Value of 1- kg live body weight equals 60 LE (2018)
[c]Assuming that the relative economic efficiency of control diet equals 100
R_1 Control ration contained 16% soybean meal (SBM).
R_2 Replaced 50% of soybean meal (SBM) by sesame meal (SM).
R_3 Replaced 100% of soybean meal (SBM) by sesame meal (SM).

not be the sole cause of the changes in the water consumption.

Also, Omer et al. (2012) noted that sheep received rations composed of 50% concentrate feed mixture + 50% of peanut vein hay, beans straw, kidney beans straw, or linseed straw increased ($P < 0.05$) drinking water compared to control group that offered ration composed of (50% concentrate feed mixture + 50% berseem hay) Also, they recorded that the corresponding values of drinking water were 3088, 3742, 4650, 3660, and 3038 ml/h/day for control and the other four experiment groups mentioned above. On the other hand, Ahmed and Abdalla (2005) showed that replacing 50% of cotton seed cake (CSC) by sesame seed cake (SSC) in yearling sheep had no effect on water intake (3.04 vs. 3.00 l/kg DM intake) for CSC and SSC, respectively; we think that ash content in the two sources in the same range had not caused any adverse effect on quantity water consumption.

Ahmed and Abdalla (2005) noted that replacing 50% of cotton seed cake (CSC) with sesame seed cake (SSC) in yearling sheep had no effect on ruminal pH and total volatile fatty acids (TVFAs) concentration; however, NH_3-N concentration was decreased ($P < 0.05$) at the same time of take with the rumen liquor samples in our study (3 h post feeding). The corresponding values were 6.44 vs. 6.54 for ruminal pH, and 33.7 vs. 29.6 for TVFAs and 56.7 vs. 30.76 for ammonia nitrogen (NH_3-N) concentration for the group sheep which received CSC and SSC, respectively. The optimal value for microbial growth and digestion of fiber pH was 6.0–7.0 (Weimer 1996). Mold and Orskov (1984) demonstrated that cellulose digestion was limited when ruminal pH was below 6.0. Staples et al. (1984) noted that the optimum pH value for rumen cellulolytic bacteria was ranged "between" 5.8 and 6.3. This range was almost in the same range to that obtained in our study. On the other hand, both Slyter et al. (1979) and Pan et al. (2003) noted that increased ruminal NH_3-N (22.5 mg %) might increase ruminal pH, TVF's production, and stimulated cellulolytic bacteria activity in the rumen. Also, Kanjanapruthipong and Leng (1998) showed that protozoan, fungal, and bacterial populations in the rumen were influenced by the levels of ruminal NH_3-N.

The cost per kilogram gain was highest for lambs fed the control feed, meanwhile, the incorporation of sesame oil cake reduced cost of gain. This was related to lower costs of rations containing sesame oil cake (Abo Omar 2002). On the other hand, Fitwi and Tadesse (2013) showed that using 300 g DM of sesame seed cake was potentially more feasible and economically beneficial for growing sheep. Also, Mahmoud and Bendary (2014) noted that the use of sesame seed meal reduced feed cost, and therefore it can be used to improve total revenue, net revenue, economic efficiency, and relative economic efficiency in ration on performance of growing lambs and calves. Moreover, Mahmoud and Ghoneem (2014) reported that there was a decrease in the feed cost per 1 kg 7% fat corrected milk (FCM) in Egyptian lactating buffaloes fed ration composed of (50% roughage and 50% concentrate feed mixture that contained 50% sesame seed meal) in comparison with control ration. Meanwhile, El-Nomeary Yasser et al. (2015) found that incorporation sesame seed meal in rabbit diets supplemented with black cumin, mustard, sesame, and rocket seed meals improved relative economic efficiency that reached to 140% in comparison with the control diet that considered 100%.

Conclusion

Sesame seed meal can be a successful partial or complete replacement soybean meal in lamb rations without any deleterious effect and while improving economic efficiency.

Abbreviations

ADF: Acid detergent fiber; ADG: Average daily gain; ADL: Acid detergent lignin; AOAC: Official Methods of Analysis; CF: Crude fiber; CFM: Complete feed mixtures; CP: Crude protein; CSC: Cotton seed cake; DCP: Digestible crud protein; DE: Digestible energy; DM: Dry matter; DMI: Dry matter intake; EE: Ether extract; FAO: Food and Agriculture Organization; FC: Feed conversion; FI: Feed intake; FW: Final weight; GE: Gross energy; IW: Initial weight; LBW: Live body weight; LE: Egyptian pound; NDF: Neutral detergent fiber; NFC: Non-fibrous carbohydrates; NFE: Nitrogen-free extract; NH_3-N: Ammonia nitrogen; NRC: National Research Council; OM: Organic matter; R_1: Control ration contained 16% soybean meal; R_2: Replaced 50% of soybean meal by sesame meal; R_3: Replaced 100% of soybean meal by sesame meal; SBM: Soybean meal; SM: Sesame meal; SPSS: Statistical package for Social Sciences; SSC: Sesame seed cake; TBWG: Total body weight gain; TDN: Total digestible nutrients; TVFAs: Total volatile fatty acids

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Authors' contributions

HA-AAO cooperated in the plane of work, field work, chemical analysis, data calculations, statistical analyses of data, and writing of the MS and helped in the publication. SMA cooperated in the plane of work, field work, and revision of the MS and helped in the publication. SSA-M cooperated in the plane of work and field work and followed the publication with the journal (corresponding author). BAB contributed in providing facilities. MFEK provided experimental animals and facilities. EHE cooperated in the chemical analysis and blood sample analysis. All authors read and approved the final manuscript.

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