Animal Feed Science and Technology 306 (2023) 115820

Contents lists available at ScienceDirect

Animal Feed Science and Technology

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

Black cumin meal (*Nigella sativa*) as an alternative feed resource during the suckling period of Awassi ewes: Assessments of performance and health

Belal S. Obeidat [a,*], Ja'far Al-Khaza'leh [b], Ahmed M. Alqudah [c]

[a] Department of Animal Production, Faculty of Agriculture, Jordan University of Science and Technology, Irbid 22110, Jordan
[b] Faculty of Agricultural Technology, Al-Balqa Applied University, P.O. Box 19117, Al-Salt, Jordan
[c] Biological Science Program, Department of Biological and Environmental Sciences, College of Art and Science, Qatar University, Doha, Qatar

ARTICLE INFO

Keywords:
Awassi ewes
Black cumin meal
Blood parameters
Milk production and composition

ABSTRACT

This study was designed to investigate the effectiveness of different Black cumin meal (BCM) dietary treatments during the suckling period on lactating performance and health of multiparous Awassi ewes. We randomly allocated 27 nursing Awassi ewes (4–5 years age; 50.2 ± 1.42 kg body weight) to one of three equally dietary treatments: 1) control diet, no feed BCM (CON), 2) BCM50 diet (50 g/kg of dietary dry matter (DM) and; 3) BCM100 diet (100 g/kg BCM of dietary DM). The results showed that there are no significant differences at $P \geq 0.67$ among the three treatment groups in measured parameters like intakes of DM and crude protein (CP). However, the BCM100 group showed greater ($P < 0.0001$) ether extract (EE) intake compared to both the BCM50 and CON groups and ewes exhibited greater ($P < 0.02$) metabolizable energy intake in BCM100 and BCM50 groups than the CON group. The digestibility of CP and neutral detergent fiber improved ($P < 0.05$) in the BCM100 and BCM50 diets compared to the CON diet. The acid detergent fiber digestibility tended to be higher ($P = 0.08$) in the BCM100 and BCM50 diets compared to the CON diet. However, the digestibility of DM and EE did not show significant differences ($P \geq 0.17$) among the three treatment groups. Nitrogen retained as (g/d) and retention as a percentage (g/100 g) were greater ($P < 0.01$) in the BCM100 and BCM50 diets compared to the CON diet. The final body weight and average daily gain of the lambs in the BCM50 and BCM100 groups increased compared with the CON group ($P \leq 0.02$). The BCM100-treated group had greater milk yield per day ($P \leq 0.05$) compared to the CON group. The content of fat, protein, lactose, solid-not-fat (SNF), and total solids (TS) % did not differ among the three groups. The BCM100-treated group had higher ($P \leq 0.03$) fat and TS milk yields (g/d) compared to the BCM50-treated group and CON group. However, fat and TS milk yields were similar between the BCM50 treatment group and the CON group. The BCM100-treated group had a greater SNF yield per day ($P \leq 0.05$) compared to the CON group. However, SNF yields in BCM treatment groups and between BCM50 group and CON group were similar. Moreover, the average protein and lactose yield of milk were significantly higher in the BCM100 diet than CON diet. Feed efficiency tended to be greater in BCM-treated ewes than the CON ewes. Moreover, the cost/kg of milk produced was lower ($P <$ 0.01) in the BCM diets than in the CON diet. Ewes fed a BCM100 had higher energy-corrected milk than other groups. The analysis did not detect differences in the blood serum metabolites in all treatments. In conclusion, this study suggests that dietary inclusion of different levels of

* Corresponding author.
E-mail address: bobeidat@just.edu.jo (B.S. Obeidat).

https://doi.org/10.1016/j.anifeedsci.2023.115820
Received 15 August 2023; Received in revised form 17 October 2023; Accepted 26 October 2023
Available online 28 October 2023
0377-8401/

BCM showed a positive influence on most lactating characteristics and economic performance for the lambs and lactating Awassi ewes, and could be used as a good alternative feed source in ruminant feeds.

1. Introduction

In Jordan, 3.889 million heads of sheep are the most abundant livestock species that can thrive in the different agroecological zones and production systems (Ministry of Agriculture, 2021). Raising of Awassi sheep is valuable as they are an important contributor to the livelihood of farmers, food security and poverty reduction particularly in the rural areas (Al-Khaza'leh et al., 2015a). In spite of the aforementioned, sheep production in Jordan and worldwide is faced with many challenges such as feed shortage, and high feed prices (Al-Khaza'leh et al., 2015b). By taking into account that feeds prices forms the highest part of the total variable costs in small ruminant production (Al-Khaza'leh, 2020), shifting to use alternative feeds such as by-products to feed animals could be an effective strategy to alleviate the cost of production, improve the economic performance of small ruminants and in turn enhance profitability (Obeidat, 2021).

Black cumin meal (BCM) is one of the by-products produced from black cumin seed that can be utilized as alternative feed. Black cumin (*Nigella sativa*) is an annual plant-based herb belonging to the Ranunculaceae family. It is widely planted in many regions of the world, mainly in the Middle East region (Ali and Blunden, 2003). Black cumin seed has diverse utilizations, it can be used as a food additive or medicinal herb, and it contains various active phytochemicals and vital nutrients (Abdul Hannan et al., 2021; Ahmad et al., 2021; Zaky et al., 2021).

The oil extraction process of Black cumin seeds results in the production of a large biomass (e.g. meal), which represents 700–750 g/kg of black cumin seed (Tekeli, 2014). This meal is a significant by-product that is rich in protein, fibers, carbohydrates, vitamins, phenolic, and antioxidants (Kour and Gani, 2021; Mariod et al., 2009) as well as essential amino acids (Atta, 2003). A study by Abdel-Magid et al. (2007) concluded that the inclusion of BCM in ration as a substitute for 30–60 % soybean meal is recommended to improve the growth performance of growing calves and reduce the cost of feeding. Moreover, Mahmoud and Bendary (2014) reported that using *Nigella sativa* meal as a source of protein in rations of growing lambs and calves did not have detrimental effects on their performance and could be used to enhance profitability by reducing the cost of feeding. Furthermore, other studies showed that including BCM as an alternative feed in the diets of growing lambs improved growth performance, profits, and carcass characteristics without affecting lamb meat quality (Obeidat, 2021; Obeidat, 2020).

The hypothesis of this study is that dietary inclusion of appropriate BCM levels during the suckling period of nursing ewes could improve growth performance, economic value, and healthiness of ewes, milk production and its composition, blood metabolites, and enhancing profitability. Therefore, the objective of this study was to assess the effects of the inclusion of different levels of BCM in the diet during the suckling period on milk production and composition, the growth and health of ewes and their lambs.

Table 1
Ingredients and chemical composition of diets fed black cumin meal (BCM) to Awassi ewes.

Item	Diet[a]		
	CON	BCM50	BCM100
Ingredients (g/kg DM)			
Barley grain, whole	500	480	460
Soybean meal, 440 g/kg CP (solvent)	200	170	140
Wheat straw	280	280	280
Black cumin meal[b]	0	50	100
Salt	10	10	10
Limestone	9	9	9
Vitamin-mineral premix[c]	1	1	1
Feed cost/ton (US$)[d]	399	375	353
Nutrients			
Dry matter, g/kg	912	908	904
Crude protein, g/kg DM	161	161	161
Neutral detergent fiber, g/kg DM	293	298	303
Acid detergent fiber, g/kg DM	194	196	197
Ether extract, g/kg DM	19	24	29
Metabolizable energy, Mcal/kg	2.05	2.18	2.31

[a] Diets were: 1) the control diet (CON), 2) 50 (BCM50, and 100 g/kg BCM (BCM100) of dietary dry matter (DM).
[b] Contained 32.8 %, 63.8 %, 49.4 % and 12.2 % CP, NDF, ADF and EE, respectively, on DM basis.
[c] Composition per kg contained vitamin A, 600,000 IU; vitamin D3, 200,000 IU; vitamin E, 75 mg, vitamin K3, 200 mg; vitamin B1, 100 mg; vitamin B5, 500 mg; lysine 0.5 %; DL-methionine, 0.15 %; manganese oxide, 4000 mg; ferrous sulphate, 15,000 mg; zinc oxide, 7000; magnesium oxide, 4000 mg; potassium iodide, 80 mg; sodium selenite, 150 mg; copper sulphate, 100 mg; cobalt phosphate, 50 mg; dicalcium phosphate, 10,000 mg.
[d] Calculated based on the prices of diet ingredients of the year 2023.

2. Materials and methods

2.1. Experimental animals, diets, and design

The study was conducted at the Agricultural Research and Training Unit at the Faculty of Agriculture/Jordan University of Science and Technology (JUST). Geographically, the station is located in northern Jordan at 32°30`N latitude, 510 m elevation. The climate of the station is characterized by semi-arid conditions with around 170 mm of annual rainfall. The Animal handling and study procedures were performed according to the guidelines set out by the JUST Institutional Animal Care and Use Committee (Protocol #: (16/04A/12/459AA).

A total of 27 nursing Awassi ewes of about four years of age and body weight (BW) average of 50.2 ± 1.42 kg and their (27) single lambs of about 3−4 days old and average initial BW of 5.5 ± 0.26 kg) with approximately equal performance characteristics were used in the study. Animals were randomly selected to the feeding treatments: a control diet (CON; n = 9), BCM50 diet (50 g/kg BCM of dietary dry matter (DM); n = 9), and BCM100 diet (100 g/kg BCM of dietary DM; n = 9). The diets of all lactating ewes in all experimental groups were isonitrogenous (160 g/kg CP of dietary DM) and prepared according to the requirements proposed by the NRC (2007) The ingredients and chemical composition of diets are listed in Table 1.

The experimental study consisted of two trials: In the first trial, animals were acclimatized to the experimental diets and pens over 1 week before the 8-week experiment, and in the second trial, the selected ewes were kept for 3-days of adaptation prior to the data collection at 4-days.

2.2. Growth performance, milk production, and its composition

Ewes were placed in separate pens (1.5 m × 1 m for each) where regular feeding was offered daily at 8:00 a.m. At the end of each two weeks of the trial and before feeding, ewes and lambs' weights were measured. Throughout the experimental period, diets and water were available ad libitum to ewes and lambs. Leftovers were collected every day and prepared to determine the chemical analysis of DM consumption. The feed provided to the animals was adjusted daily by 10 % from the previous day in the event that the remaining feed was less than 100 g from the previous day. Two weeks after starting the study, the yield composition and milk were assessed on a basis of two weeks. To quantify milk yield of nursing ewes, milk release was induced by intravenously administering 0.75 mL oxytocin, and ewes were then milked by hand at 08:00 by experienced labor. Then, a period of 3 h was left before ewes were subjected to the second dose of oxytocin, and milked again, and the milk yield was registered. In between two periods of dosage, lambs were kept away from their mothers. Daily milk yield intervals were adjusted and estimated over 24 h as (3 h × 8). Then, 125 mL of the collected milk was used to measure the following parameters: total solids, fat, and CP. In addition, milk energy value (MEV; kcal / kg) and energy corrected milk (ECM) were calculated as described by Obeidat (2023).

2.3. The digestibility of nutrients and nitrogen (N) balance

Random selection of a group of five ewes from each treatment was kept in separate metabolic crates with a size of 100 cm × 80 cm to measure the digestibility of nutrients and N balance. Details of the analyses of the digestibility of nutrients, feed intake, orts, and fecal output, in addition to the procedure of DM, CP, neutral detergent fiber (aNDF), acid detergent fiber (ADF), and ether extract (EE) contents measurements were reported by the Association of Official Analytical Chemists (AOAC) and Obeidat (2023).

Determination of N content in the urine samples was first performed by collecting urine using plastic containers with 50 mL of 6 N HCL solution to prevent ammonia losses by bacterial or enzymatic factors and then weighed and recorded. The N content and N intake measurements were previously described by Obeidat (2023). Likewise, N lost in urine was estimated as N content in the urine times urinary output. Then, retained N (g/day) was estimated with the formula [N intake – (fecal + urinary output)]. Nitrogen retention (g/100 g) was obtained by dividing retained nitrogen by ingested nitrogen. At the end of the trial, fecal and urine samples were gathered together for each ewe. A forced ventilation oven at 55 °C was used to dry the fecal samples for a few days to obtain a constant weight, then weighed to measure the DM content. After being pulverized, samples passed through a 1-mm sieve, and then stored at room temperature in containers for further analysis according to the AOAC's proposed methods (1990).

2.4. Blood analyses

Through the jugular veins of ewes, blood samples were obtained from each ewe using plain vacutainers at 08:00 h on the last day of the experiment before feeding. At 9:00 a.m., blood samples were centrifuged at 1008 g for 15 min to separate blood plasma. Then, samples of serum were taken and kept at −20 °C. The blood biochemical parameters including serum glucose, urea N content, cholesterol, low-density lipoprotein (LDL), high-density lipoprotein (HDL), triglycerides, creatinine, aspartate aminotransferase (AST), alkaline phosphatase (ALP)) and alanine aminotransferase (ALT) were measured according to the manufacturer's guidelines for spectrophotometer instruments and commercial kits (BioSystems, S. A. Costa Brava, Barcelona, Spain).

2.5. Statistical analyses

The data were submitted for statistical analysis using SAS software 8.1 (SAS Institute, 2000) as a completely random design. The variance of analysis (ANOVA) for all studied traits was calculated at the probability level $P \leq 0.05$ including the treatment, week, and their interaction. Because no interaction was observed, the only influencing variable was treatment, which affected outcome variables such as milk composition, and yield.

$$Y_{ijk} - \mu + B_i + \varepsilon_{ij}$$

Where:
$Y_{ij}$the dependent variable.
μ is the overall mean.
B_i is the treatment effect.
ε_{ij} is the random error.

3. Results

3.1. Nutrient intake, nutrients digestibility, and N balance

The influence of BCM on DM intake is presented in Table 2. Intakes of DM, CP, aNDF, and ADF did not differ significantly among the three treatment groups ($P \geq 0.67$). Ewes in the BCM100 group showed significantly higher ($P < 0.0001$) EE intake compared to both the BCM50 and CON groups and exhibited significantly greater ($P < 0.02$) ME in the BCM100 and BCM50 groups than the CON group.

The influence of BCM on nutrient digestibility and N balance of nursing Awassi ewes is presented in Table 3. The digestibility of DM and EE did not show significant differences ($P \geq 0.17$) among the three treatment groups. The digestibility of CP and aNDF was improved ($P < 0.05$) in the BCM100 and BCM50 groups compared to the CON group. The ADF digestibility tended to be higher ($P = 0.08$) in lactating ewes who received BCM100 and BCM50 diets compared to the CON diet.

There were no significant differences in the N intake among the three experimental groups ($P > 0.10$). The N excreted in urine tended to be lower ($P = 0.08$) in lactating ewes who received BCM100 and BCM50 diets compared to the CON diet. However, the N lost in feces decreased significantly ($P < 0.05$) in lactating ewes who received BCM100 and BCM50 in their diets compared to the CON diet. Moreover, Nitrogen retained as (g/d) and retention as a percentage (g/100 g) increased significantly ($P < 0.01$) with the addition of either level of BCM to the diet.

3.2. Ewes' body weight and pre-weaning growth of their lambs

Ewes' and lambs' body weight responses to dietary treatments are shown in Table 4. The inclusion of BCM did not have any significant effects on live weight of lactating ewes and there was a 4.1 %, 5.1 % and 5.7 % decrease in the average final BW of ewes for CON, BCM50 and BCM100 treatment groups, respectively ($P \geq 0.42$). The final BW and ADG of the lambs in BCM50 and BCM100 groups were significantly higher compared to the CON group ($P \leq 0.02$).

3.3. Milk production and composition of nursing Awassi ewes

The measurements of milk production and composition of suckling Awassi ewes fed with different levels of BCM are presented in Table 5. The average milk yield was significantly higher ($P = 0.05$) in lactating ewes received the BCM100 diet compared to the CON diet but there were no significant differences in milk yield between BCM treatment groups and between the BCM50 diet and CON diet. The chemical analysis of milk samples indicated that the fat, protein, lactose, SNF, and TS % in all treatment groups were similar. Fat and TS milk yields (g/d) were significantly higher ($P \leq 0.03$) in lactating ewes who received the BCM100 diet compared to BCM5 and CON diets. However, fat and TS milk yields were similar between the BCM5 treatment group and the CON diet.

The average SNF yield of milk was significantly higher ($P = 0.05$) in lactating ewes who received the BCM100 diet compared to the CON diet but it was similar between BCM treatment groups and between the BCM50 diet and CON diet. Moreover, the average protein and lactose yield of milk tended to be significantly higher ($P = 0.06$, 0.07, respectively) in lactating ewes who received the BCM100 diet compared the to CON diet.

The feed efficiency in terms of the amount of feed consumed to milk produced tended to be significantly higher in lactating ewes that received the BCM100 diet compared to the CON diet. Also, the milk production cost was significantly lower for the BCM diets

Table 2
The influence of black cumin meal (BCM) on nutrients intake of nursing Awassi ewes.

	Diets[a]				
Item	CON	BCM50	BCM100	SE	*P* value
Dry matter (DM) intake, g/d	1991	1971	2012	66.4	0.9500
Crude protein, g/d DM	321	318	323	10.7	0.9470
Neutral detergent fiber, g/d DM	582	587	607	19.9	0.6661
Acid detergent fiber, g/d DM	387	386	394	13.0	0.8861
Ether extract, g/d DM	37[a]	47[b]	58[c]	1.7	<0.0001
Metabolizable energy, Mcal/d	3.93[a]	4.30[ab]	4.61[b]	0.149	0.0173

[a] Diets were: 1) the control diet (CON), 2) 50 (BCM50, and 100 g/kg BCM (BCM100) of dietary dry matter (DM).

Table 3
The influence of black cumin meal (BCM) on nutrients digestibility and N balance of nursing Awassi ewes.

Item	Diets[a]			SE	*P* value
	CON	BCM50	BCM100		
Digestion, %					
Dry matter	82.5	84.1	84.5	1.42	0.1714
Crude protein	76.1[a]	82.4[b]	82.1[b]	1.74	0.0465
Neutral detergent fiber	60.1[a]	69.2[b]	66.8[b]	2.33	0.0400
Acid detergent fiber	56.4	61.8	59.6	1.45	0.0807
Ether extract	77.4	82.6	81.5	3.28	0.1947
N balance					
N intake, g/d	43.3	44.3	45.6	2.69	0.3635
N lost in urine, g/d	11.6	9.9	10.7	0.54	0.0781
N lost feces, g/d	9.9[b]	7.1[a]	7.9[a]	0.67	0.0486
Retained N, g/d	21.8[a]	27.3[b]	26.9[b]	2.42	0.0092
Retention, g/100 g	49.5[a]	61.3[b]	58.9[b]	2.54	0.0049

[a] Diets were: 1) the control diet (CON), 2) 50 (BCM50, and 100 g/kg BCM (BCM100) of dietary dry matter (DM).

Table 4
The influence of black cumin meal (BCM) on ewes' body weight and pre-weaning growth of their lambs.

Item	Diets[a]			SE	*P* value
	CON	BCM50	BCM100		
Ewes					
Initial body weight, kg	48.6	49.9	52.0	1.42	0.2520
Final body weight, kg	46.7	47.5	49.2	1.41	0.4426
Body weight change, kg	-1.44	-1.83	-2.11	0.660	0.4237
Lambs					
Initial body weight, kg	5.33	5.77	5.64	0.241	0.4054
Final body weight, kg	17.24[a]	18.75[b]	19.95[b]	0.553	0.0033
Average daily gain, g/d	212.7[a]	231.8[ab]	255.5[b]	9.95	0.019

[a] Diets were: 1) the control diet (CON), 2) 50 (BCM50, and 100 g/kg BCM (BCM100) of dietary dry matter (DM).

Table 5
The influence of black cumin meal (BCM) on milk production and composition of nursing Awassi ewes.

Item	Diets[a]			SE	*P* value
	CON	BCM50	BCM100		
Milk production, g/d	1560[a]	1692[ab]	2040[b]	135.6	0.0523
Milk composition, %					
Fat	7.52	7.04	8.01	0.370	0.2028
Protein	4.51	4.54	4.48	0.042	0.5472
Lactose	6.60	6.59	6.61	0.04	0.7276
Solid-not-fat	11.81	12.01	11.87	0.103	0.3973
Total solids	19.3	19.1	19.9	0.39	0.3264
Milk composition, g/d					
Fat	117.1[a]	119.2[a]	163.3[b]	12.50	0.0242
Protein	70.3[a]	76.9[ab]	91.4[b]	6.06	0.0607
Lactose	102.7[a]	111.7[ab]	133.6[b]	9.11	0.0658
Solid-not-fat	184.0[a]	203.2[ab]	242.0[b]	16.11	0.0512
Total solids	301.1[a]	322.2[a]	405.3[b]	27.13	0.0288
Feed to milk ratio	1.32[b]	1.23[ab]	1.04[a]	0.885	0.0918
Milk cost ($US/kg)	52.6[b]	45.1[a]	36.7[a]	3.21	0.0100
MEV[b]	277.5	273.5	281.5	3.10	0.2095
ECM[c]	2.51[a]	2.62[a]	3.41[b]	0.235	0.0247

[a] Diets were: 1) the control diet (CON), 2) 50 (BCM50, and 100 g/kg BCM (BCM100) of dietary dry matter (DM).
[b] MEV = milk energy value
[c] ECM = energy corrected milk

compared to the CON diet. A comparison between the three groups also shows that lactating ewes who received a BCM100 in their diet had greater energy-corrected milk (ECM) ($P = 0.03$) compared to other groups. However, the milk energy value (MEV) was similar among the three experimental groups.

3.4. Blood parameters of nursing Awassi ewes

The effect of BCM on serum metabolite profiles of nursing Awassi ewes is shown in Table 6. All blood serum metabolites were similar among the three experimental groups ($P \geq 0.12$).

4. Discussion

Providing a sufficient diet for lactating mothers is critical to ensure their production and health. However, in most cases providing a sufficient diet during the suckling period is costly and poses burdens on the farmers which forces them to search for a solution to alleviate the problem. One of the strategies that has been implemented by farmers to cope with the problem is shifting to use alternative feeds in the diet that are available, nutritious, and inexpensive (Obeidat et al., 2019; Aloueedat et al., 2019). In most previous studies, the inclusion of *Nigella sativa* in the diet of animals resulted in different effects concerning performance and health. However, experimental animal use, physiological state of the animal, age, ration composition, *Nigella sativa* type and level used, and nutrient contents in meals were among the major factors that contributed to that difference.

In the present study, the ingredients and chemical composition of diets indicate that the experimental rations are similar in all ingredients except for the BCM level of dietary DM, barley grain, and soybean meal. Moreover, no major differences were found among the tested rations for all nutrient contents of this study except for EE content. However, the slightly highest contents of EE observed in the ration of BCM100 followed by BCM50 and CON diet could be ascribed to an increased replacement portion of soybean meal with BCM (Mansour et al., 2013; Obeidat, 2020; Taha, 2017). In the present study, the feed cost of BCM100 ration accounted for the lowest value (353 US$/ton) followed by BCM50 (375 US$/ton) and CON ration (399 US$/ton). This variation in the cost among rations was linked to an increased replacement portion of soybean meal and barley grains with BCM. Hence, using BCM as an alternative feed for feeding Awassi ewes is economically beneficial.

The observed increase in EE and ME intakes for the ewes fed BCM diets could be related to the increase in contents of EE observed in BCM diets. However, DM, CP, aNDF, and ADF intakes were similar among the three diets. In contrast, the previous study by Obeidat (2020) reported an improvement in DM, CP, aNDF, ADF, EE and ME intakes in lambs when the BCM included 150 g/kg in diets. A study by Cherif et al. (2018) also reported that enrichment of a diet with 12 g/kg Nigella sativa seeds improved nutrient intakes for Barbarine lambs.

In the current study, the digestibility of some nutrients improved and others tended to be improved or not affected by adding the BCM. The improvement in digestibility of CP and aNDF for lactating ewes fed diet treated with BCM could be ascribed to the antimicrobial effect of BCM, which may enhance rumen microorganisms and their digestion capabilities. This finding is consistent with the previous study by Abdullah and Farghaly (2019) that showed an increase in nutrient digestibility of growing Farafra lambs with an increasing replacement rate of cotton seed meal from 33.3 % to 66.7 % by BCM. A study by Abdel-Magid et al. (2007) also showed that the replacement of 30 or 60 % of soybean meal by BCM in the diet of calves improved CP digestibility. A study by Retnani et al. (2019) also reported improvement in the digestibility of CP of Indonesian male lambs fed the diet treated with BCM at the rate of 100 and 200 g/kg. However, according to a study by Cherif et al. (2018) the apparent digestibility of DM, OM, CP, and aNDF nutrients was not affected by including the Nigella seeds in the low and high-concentrate diets of lambs.

In the current study, lactating ewes showed positive N retained and retention when fed a diet treated with both BCM levels than the CON diet group. This finding can be linked to the increased CP digestibility in the BCM diet groups than in the CON diet group. This result is in agreement with a previous study conducted on growing lambs fed BCM at a rate of 100 and 200 g/kg of the total diet. (Retnani et al., 2019).

The similarity in the final BW of ewes in the three groups could be explained by differences in their production performance. When adjusted for production performance, the final BW could be varied based on the treatment. However, the final BW and ADG of the growing lambs in the BCM50 and BCM100 groups were heavier than the CON group. Such results could be mainly a reflection of the

Table 6
The influence of black cumin meal (BCM) on blood parameters of nursing Awassi ewes.

Item	Diets[a]			SE	*P* value
	CON	BCM50	BCM100		
Blood urea nitrogen, mg/dL	23.9	21.7	20.5	1.18	0.1190
Glucose, mg/dL	42.6	39.2	39.1	2.40	0.5280
Cholesterol, mg/dL	66.1	62.7	67.2	3.49	0.6378
HDL, mg/dL[b]	40.6	41.9	45.8	2.43	0.2666
LDL, mg/dL[b]	20.6	16.8	17.3	1.53	0.1869
Triglycerides, mg/dL	24.7	20.1	20.7	2.10	0.2738
Creatinine, mg/dL	0.70	0.63	0.67	0.033	0.3682
AST, IU/L[b]	32.4	25.7	29.9	3.01	0.3009
ALT, IU/L[b]	8.4	5.4	5.6	1.28	0.1945
ALP, IU/L[b]	27.4	29.9	27.0	3.95	0.8578

[a] Diets were: 1) the control diet (CON), 2) 50 (BCM50, and 100 g/kg BCM (BCM100) of dietary dry matter (DM).
[b] HDL: high-density lipoprotein, LDL: low-density lipoprotein, AST: aspartate aminotransferase, ALT: alanine aminotransferase, ALP: alkaline phosphatase.

higher performance and milk yield of lactating ewes received BCM diets compared with CON diet. This observation is consistent with previous study results such as by Abdel-Magid et al. (2007) who observed enhancement in ADG of growing calves fed a diet containing BCM compared with the control diet, by Habeeb et al. (2012) who reported an increase in ADG and final BW of kid goats supplemented with *Nigella sativa*, by Retnani et al. (2019) who also reported higher increase in ADG of male lambs fed the diet provided with BCM at rate of 100 and 200 g/kg of the total diet, by El-Ghousein (2010) who found improvement in ADG of Awassi lambs by the addition of *Nigella sativa seeds* to the basal diet. In the contrary, other studies indicated that total weight gain was not affected in calves fed a diet supplemented with BCM at 70 and 110 g/kg of the total diet (Mansour et al., 2013).

In the present study, BCM inclusion affected the overall milk yield and some milk chemical constituents. The increase in milk yield in the present study could be attributed to increased intakes of some nutrients, digestibility and utilization in the lactating ewes fed on the BCM diet. The addition of BCM at a higher level (100 g/kg of dietary DM) resulted in higher milk yield in lactating ewes compared to CON. Similar to our finding, Abd-El Moty et al. (2015) reported improvement in milk yield of Ossimi lactating ewes suckling single or twin lambs when fed a diet supplemented with *Nigella sativa* seeds. El-Basiony et al. (2015) also indicated an increase in milk quantity and quality of Damascus lactating goats when *Nigella sativa* was added to the diet. Moreover, El-Ghousein (2010) found improvement in milk yield and composition when Awassi ewes were fed a diet supplemented with *Nigella sativa* seeds. A study by Nasser (et al. (2012) also stated that the addition of BCM at 260 g/kg of the ration improved the milk yield of dairy cows.

In the present study, % of milk components were not affected by dietary inclusion of BCM. However, some of the milk component yields (g/d) were influenced by including different BCM levels. In contrast, one previous study reported a significant increase in milk fat %, protein %, and milk energy of lactating ewes by the inclusion of *Nigella sativa* seeds in the diet (Abd-El Moty et al., 2015). Mohammed and Al-Suwaiegh (2023) also found that the supplementation of Ardi goats with N. sativa seeds at 10 and 20 g/kg diet increased the concentration of protein, lactose, SNF, fat, and ash in milk. A study by El-Ghousein (2010) showed that the addition of *Nigella sativa* seeds to the basal ration of Awassi ewes improved percentages of milk composition in terms of total protein, ash and SNF.

In the present study, the amounts of energy in the milk in terms of ECM were statistically and numerically increased with increasing the level of BCM in the diet. This indicates the lactating ewes in the BCM100 and BCM50 groups were performing well compared to the CON group when the amount of milk produced adjusted to percent fat and percent protein.

The economic feed efficiency in terms of the amount of milk produced per amount of DM consumed In this study tended to be improved in lactating ewes that received BCM diets compared to the CON diet. Also, the milk cost was significantly reduced for the BCM diet compared to the CON diet. This improvement in feed efficiency and profitability could be ascribed to the enhancement of the ration formulation by including inexpensive alternative feed sources, namely BCM in the diet. Similarly, a study by Mahmoud and Bendary (2014) reported a significant improvement in economic efficiency and profitability when BCM was used in combination with sesame seed meal as a source of protein in rations of growing lambs and calves.

In the current study, serum metabolite levels were considered as a reliable indicator of the animal's health status after including BCM in the diet. All blood serum metabolites concentrations in this study were not affected by BCM inclusion compared to the CON group; depicting that there was no apparent harmful effect of BCM on the health of the lactating ewes and thus safe for usage in ruminant nutrition. Other studies also reported that supplementation of diet with *Nigella sativa* had no adverse effects on blood metabolites profiles (Mohammed and Al-Suwaiegh, 2023; Retnani et al., 2019; Longato et al., 2015; El-Ghousein, 2010).

5. Conclusions

Due to the fact that the cost involved in feeding ruminants is very high, the demand to find suitable alternative natural feed sources is critical. This study revealed that using two levels of BCM in the diet as potential alternative feed had comparable positive effects on some growth performance characteristics and economic performance of lactating Awassi ewes and their lambs. Feeding of BCM improved lactating performance, enhanced feed efficiency, and mitigated the cost of milk production with no detrimental effect on animal health. The present study findings suggested that dietary inclusion of BCM with appropriate levels is recommended and can be used alternatively to other protein and energy sources that are very expensive.

Declaration of Competing Interest

There is no conflict of interest with anyone regarding this manuscript.

Acknowledgments

The author thanks Eng. Majdi Abu-Ishmais, Eng. Nawazat Al-Smadi, and Eng. Thaer Meqdadi for their cooperation in carrying out this experiment. Thanks are extended to the Deanship of Scientific Research at Jordan University of Science and Technology funded this study (Grant #: 515/2022).

References

Abd-El Moty, A.K.I., Zanouny, A.I., El-Barody, M.A.A., Sallam, M.T., Abd El-Hakeam, A.A., 2015. Effect of *Nigella sativa* seeds supplementation on milk yield and milk composition in sheep. Egypt. J. Sheep Goat Sci. 10, 19–26.

Abdel-Magid, S.S., El-Kady, R.I., Gad, S.M., Awadalla, I.M., 2007. Using cheap and local non-conventional protein meal (Nigella sativa) as least cost rations formula on performance of crossbreed calves. Int. J. Agric. Biol. 9, 877–880.

Abdul Hannan, M.A., Rahman, M.A., Sohag, A.A.M., Uddin, M.J., Dash, R., Sikder, M.H., Rahman, M.S., Timalsina, B., Munni, Y.A., Sarker, P.P., Alam, M., Mohibbullah, M., Haque, M.N., Jahan, I., Hossain, M.T., Afrin, T., Rahman, M.M., Tahjib-Ul-Arif, M., Mitra, S., Oktaviani, D.F., Khan, M.K., Choi, H.J., Moon, I.S., Kim, B., 2021. Black Cumin (*Nigella sativa* L.): A Comprehensive review on phytochemistry, health benefits, molecular pharmacology, and safety. Nutrients 13, 1784. https://doi.org/10.3390/nu13061784.

Abdullah, M.A.M., Farghaly, M.M., 2019. Impact of partial replacement of cottonseed meal by Nigella *sativa* meal on nutrients digestibility, rumen fermentation, blood parameters, growth performance of growing lambs Egypt. J. Nutr. Feeds 22 (2), 11–20 (Special Issue).

Ahmad, M.F., Ahmad, F.A., Ashraf, S.A., Saad, H.H., Wahab, S., Khan, M.I., Ali, M., Mohan, S., Hakeem, K.R., Athar, M.T., 2021. An updated knowledge of Black seed (*Nigella sativa* Linn.): Review of phytochemical constituents and pharmacological properties. J. Herb. Med. 25, 100404 https://doi.org/10.1016/j.hermed.2020.100404.

Ali, B.H., Blunden, G., 2003. Pharmacological and toxicological properties of *Nigella sativa*. Phyto. Res. 17, 299–305. https://doi.org/10.1002/ptr.1309.

Al-Khaza'leh, J., Reiber, C., Al Baqain, R., Zárate, A.V., 2015a. A comparative economic analysis of goat production systems in Jordan with an emphasis on water use. Livest. Res. Rural Dev. 27 (5), 81.

Al-Khaza'leh, J., Reiber, C., Al Baqain, R., Valle Zárate, A., 2015b. Drinking water sources, availability, quality, access and utilization for goats in the Karak Governorate. Jordan. Trop. Anim. Health Prod. 47, 163–169.

Al-Khaza'leh, J.M., 2020. Impact of feed subsidy removal on the economic success of small ruminant farming in northern badia of Jordan. J. Exp. Bio. Agric. Sci. 8 (2), 193–200.

Aloueedat, M.K., Obeidat, B.S., Awawdeh, M.S., 2019. Effects of partial replacement of conventional with alternative feeds on nutrient intake, digestibility, milk yield and composition of Awassi ewes and their suckling lambs. Animals 9, 684.

AOAC, 1990. Official Methods of Analysis, 15th ed. AOAC, Washington, DC.

Atta, M.B., 2003. Some characteristics of nigella (Nigella sativa L.) seed cultivated in Egypt and its lipid profile. Food Chem. 83, 63–68.

Cherif, M., Salem, Ben, Abidi, S, H., 2018. Effect of the addition of *Nigella sativa* seeds to low or high concentrate diets on intake, digestion, blood metabolites, growth and carcass traits of Barbarine lamb. Small Rumin. Res. 158, 1–8.

El-Basiony, A.Z., Khattab, H.M., Kholif, A.M., Hadhoud, F.I.I., El-Alamy, H.A., 2015. Effect of using Echinacea purpurea, Nigella sativa and Chicorium intybus in dairy goats diet on milk production and quality: effect on digestibility, some blood parameters and milk production and quality. Egypt. J. Nutr. Feed. 18, 137–145.

El-Ghousein, S.S., 2010. Effect of some medicinal plants as feed additives on lactating awassi ewe performance, milk composition, lamb growth and relevant blood items. Egypt. J. Anim. Prod. 47, 37–49. https://doi.org/10.21608/ejap.2010.94040.

Habeeb, A.A.M., El Tarabany, A.A., 2012. Effect of Nigella sativa or curcumin on daily body weight gain, feed intake and some physiological functions in growing Zaraibi goats during hot summer season. In Proceedings of the Third International on Radiation Sciences and Applications, Hurghada, Egypt, 12–16 November 2012; p. 920.

Kour, J., Gani, A., 2021. Nigella sativa seed cake: nutraceutical significance and applications in the food and cosmetic industry. Black cumin (*Nigella sativa*) seeds: Chemistry, Technology, Functionality, and Applications. Springer, Cham, pp. 223–229.

Longato, E., Meineri, G., Peiretti, P.G., 2015. Nutritional and zootechnical aspects of *Nigella sativa*: a review. J. Anim. Plant Sci. 25 (4), 921–934.

Mahmoud, A.E.M., Bendary, M.M., 2014. Effect of whole substitution of protein source by *Nigella sativa meal* and sesame seed meal in ration on performance of growing lambs and calves. Glob. Vet. 1, 391–396.

Mansour, R.S., Nasser, A.K., Abo, N.Y., 2013. The effect of different Nigella sativa L. seed (cake) concentrations on leukocytes counts and some serum immunological parameters in calves. Tikrit J. Pure Sci. 18, 31–35.

Mariod, A.A., Ibrahim, R.M., Ismail, M., Ismail, N., 2009. Antioxidant activity and phenolic content of phenolic rich fractions obtained from black cumin (*Nigella sativa*) seedcake. Food Chem. 116, 306–312. https://doi.org/10.1016/j.foodchem.2009.02.051.

Ministry of Agriculture. 2021. Statistical annual report, Amman. Jordan. ⟨https://moa.gov.jo/EN/List/Agriculture⟩ by Numbers. Accessed 20 Jun 2023.

Mohammed, A.E.N., Al-Suwaiegh, S., 2023. Impacts of Nigella sativa inclusion during gestation and lactation on ovarian follicle development, as well as the blood and metabolic profiles of Ardi goats in Subtropics. Agriculture 13, 674. https://doi.org/10.3390/agriculture13030674.

Nasser, A.K., Abdullah, N.M., Abou, N.Y., 2012. Evaluation of supplementing *Nigella sativa* meal to local dairy cows ration on milk production, composition and nutrients digestibility. Kirkuk Univ. J. Agric. Sci. 3 (2), 52–63.

NRC, 2007. Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervide, and New World Camelids. National Academy of Sciences, Washington, DC, USA.

Obeidat, B.S., 2020. The inclusion of black cumin meal improves growth performance of growing Awassi lambs. Vet. Sci. 7. https://doi.org/10.3390/vetsci7020040.

Obeidat, B.S., 2021. The inclusion of black cumin meal improves the carcass characteristics of growing Awassi lambs. Vet. World 14 (1), 237–241.

Obeidat, B.S., 2023. Effect of Saccharomyces cerevisiae supplementation during the suckling period on performance of Awassi ewes. Trop. Anim. Health Prod. 55 (140) https://doi.org/10.1007/s11250-023-03555-x.

Obeidat, B.S., Kridli, R.T., Mahmoud, K.Z., Obeidat, M.D., Haddad, S.G., Subih, H.S., Ata, M., Al-Jamal, A.E., Abu Ghazal, T., Al-Khazáleh, J.M., 2019. Replacing soybean meal with sesame meal in the diets of lactating Awassi ewes suckling single lambs: nutrient digestibility, milk production, and lamb growth. Animals 9, 157.

Retnani, Y., Wiryawan, K.G., Khotijah, L., Barkah, N.N., Gustian, R.A., Dermawan, I.R., 2019. Growth performance, blood metabolites and nitrogen utilization of lambs fed with Nigella sativa meal. Pak. J. Nutr. 18 (3), 247–253.

SAS Institute, 2000. Base SAS® 8.1 Procedures Guide: Statistical Procedures. SAS Institute Inc., Cary, NC, USA.

Taha, E.A., 2017. A study of some wool traits of Barki sheep fed on Nigella sativa cake under desert conditions. Alex. J. Agric. Sci. 62, 341–348.

Tekeli, A., 2014. Nutritional value of black cumin (*Nigella sativa*) meal as an alternative protein source in poultry nutrition. J. Anim. Sci. Adv. 4, 797–806.

Zaky, A.A., Shim, J.H., Abd El-Aty, A.M., 2021. A review on extraction, characterization, and applications of bioactive peptides from pressed black cumin seed cake. Front. Nutr. 8, 743909 https://doi.org/10.3389/fnut.2021.743909.