



The effect of diets supplemented with *Coriandrum sativum* seeds on carcass performance, immune system, blood metabolites, rumen parameters and meat quality of lambs

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ABSTRACT. A trial was conducted to investigate the effects of dietary *Coriandrum sativum* seeds on carcass performance, immune system, blood metabolites, rumen parameters and meat quality of Lambs. 16 Sanjabi lambs of 27 ± 5.1 kg during post-weaning (97 d of age) period were randomly selected. Four diets including 0, 1, 3, and 5% coriander seeds, replaced by Alfa alfa in the diet, were considered. A 30:70 alfalfa hay: concentrate diet for a period of time (97 to 187 d of age) was used. The results showed that feed intake was significantly increased by adding coriander seeds, linearly. There was no significant difference for apparent digestibility of crude protein, crude fat, neutral and acidic detergent fiber, crude ash, rumen fluid pH and ammonia nitrogen at 0, 2 and 4 h after feeding, Meat dry matter, ash, crude protein and fat, and the meat's fatty acid profile ($p > 0.05$). Dietary coriander seeds had a significant effect on neutrophils, lymphocytes, monocytes and eosinophil's (in days 7 and 14 of trial) and blood metabolites at the middle of trial. Obtained results suggested that supplementation of coriander seed may have limited effects on nutrient digestibility, ruminal parameters, meat quality, blood cells and metabolites.

Keywords: Sanjabi lambs; fattening period; Coriander seed; growth performance.

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Introduction

The ruminants' production performance may be restricted by the fermentation process in the rumen, due to the loss of energy in the form of methane and nitrogen in the form of ammonia, preventing the release of environmental pollutants (Patra & Saxena, 2009). In recent years, edible additives such as antibiotics, ionophores, methane inhibitors and antiprotozoic agents have been successfully used to reduce this waste of energy and nitrogen in the rumen and they have increased production efficiency and reduced metabolic disorders (Cardozo, Calsamiglia, Ferret, & Kamel, 2005). Bacterial resistance is an issue which has always been of concern to these additives in livestock production. On the other hand, using antibiotic growth stimulants in animal feed has encountered social concerns and has been banned in Europe for four years (Calsamiglia, Busquet, Cardozo, Castillejos, & Ferret, 2007). Removing ionophores from ruminant animal feeds would increase production costs by 3.5 to 5 percent. Therefore, evaluation and replacement of safety feed additives seems to be necessary to maintain current production levels without increasing production costs or metabolic disorders (Cardozo et al., 2005). Indeed, paying attention to the properties of medicinal plants and using them as edible additives has opened a new horizon for research in animal nutrition (Mandal & Mandal, 2015). Various phytochemicals, including saponins, essential oils, tannins, flavonoids, have been isolated from a wide range of plant species, having beneficial effects on rumen fermentation and animal productivity (Naseri, Hozhabri, & Kafilzadeh, 2013). One of the wealthy medicinal plants is coriander.

Coriander (*Coriandrum sativum* L.) from the family Umbelliferae/Apiaceae, a glabrous aromatic and herbaceous annual plant, is a source of active aroma compounds, useful in food preparation, antibacterial, antifungal and antioxidant activities, and preventing food borne diseases and food spoilage being of secondary importance (Mandal and Mandal, 2015). Essential oils found in Coriander include Octane, β -Phellandrene, Undecane, Linalool, Nonanal, Decanal, Carvone, E-2-Decenal, 1-Decanol, Undecanal, Decyl acetate, Dodecanal, Z-2-Dodecenal, E-2-Dodecenal, E-2-Dodecen-1-ol, 1-Dodecanol, Tridecanal, E-2-

Tridecenal, 1-Tetradecanol, and Tetradecanal (El-Zaeddi, Martínez-Tomé, Calín-Sánchez, Burló, & Carbonell-Barrachina, 2016). Essential oils from leaves and seeds containing various components which acts as preservative in food products (Kalemba & Kunicka, 2003). Coriander seeds is a wealthy source of lipids which is important in the food industry (about 28.4% of the total seed weight) (Yeung & Bowra, 2011). The leaves contain a large amount of tocopherol including α and β ones, which play an important role in preventing lipid oxidation (Ganesan, Phaiphon, Murugan, & Baharin, 2013). As pointed out by Anita, Sharad, Amanjot and Ritu (2014), antioxidant profile of *C. sativum* seed extract based on mg g⁻¹ dry weight includes oxidized ascorbate (0.15), reduced ascorbate (0.136), total ascorbate (0.287), riboflavin (0.0046), tocopherol (0.181), total polyphenol (18.7), gallic acid (0.173), caffeic acid (0.08), ellagic acid (0.162), quercetin (0.608), kaempferol (0.233), involved in delay or prevent the spoilage of food. It is necessary to mention that minerals including phosphorus, calcium, sodium and potassium and amino acids including glutamine, asparagine and arginine were also found in Coriander seeds (Oganesyanyan, Nersesyanyan, & Parkhomenko, 2007).

There are several relatively published papers showing positive effect of Coriander on performance, rumen fermentation process, blood parameters, meat quality, digestion of food and feed conversion efficiency in ruminants (Nasser, Shams Al-dain, Abou, & Mahmood, 2013; Mohammed, Saeed, & Al-Jubori, 2018; Fakhraei, Siahkamari, Mansoori Yarahmadi, & Khamisabadi, 2019). Coriander seeds can be used as additive in sheep ration, resulting improved animal health, white blood cells, protein level (globulin), and wool traits (Al-Zwein, 2011). On the other hands, added coriander seeds to the diet, make a decrease in LDL cholesterol and an increase in HDL cholesterol (Chitra & Leelamma, 1997). Mohammed et al. (2018) showed that coriander seeds powder improve the immunity and energy of ewes rather than lambs in Awassi. However, there was no significant differences in the weight gain and rumen fermentation between ewes and lambs which fed by coriander powder (Mohammed et al., 2017). They also reported that no significant differences appeared in total protein, albumin, globulin, urea, triglycerides, cholesterol, LDL, HDL, VLDL, packed cell volume PCV%, HB, red blood cells RBC, GOT and GPT between ewes and lambs (Mohammed et al., 2018). Hence, in a different study, coriander supplementation also resulted in the significant decrease ($p > 0.01$) in triglyceride lipid and LDL (49.88 and 40.40% respectively) (Mohammed et al., 2018).

Based on importance of coriander in the sheep diet, the aim of current study was to investigate the effect of coriander seed supplementation on carcass performance, immune system, blood parameters, rumen development and meat quality in Sanjabi Lambs.

Material and methods

This study was carried out at Mehrgan Animal Research Station affiliated to Kermanshah Agricultural and Natural Resources Research and Education Center, Kermanshah, Iran, during the months of December, 2018 through April, 2019.

Lambs management and diets

This study was conducted on 16 Sanjabi lambs during post-weaning (97 to 187 d) period using a completely-randomized design. Sanjabi sheep breed is a fat-tailed, large-sized, well adapted to the mountainous regions and located in Kermanshah province, western part of Iran. It is mainly raising for mutton production under pastoral production system. All animals were treated for internal and external parasites and vaccinated against enterotoxaemia before the experiment started. Sanjabi lambs of mean weight about 27 ± 5.1 kg were randomly allocated into four groups each consisting of four animals. The lambs had a habitual period of feeding for a week (91 to 97 d). The lambs were fed by a diet with concentrate to forage ratios of 30:70 alfalfa hay: concentrate diet in individual stands. The selected ratio of alfalfa hay: concentrate is related to the research project that has been done. Feed distribution was performed three times a day (Morning, noon and evening).

The diets were formulated according to National Research Council (National Research Council [NRC], 2007) by using UFFDA software. The components of the diets are presented in Table 1. We had four experimental diets (treatment), the first group was fed a control diet without coriander seed; the second (coriander seed of 1%), the third (coriander seed of 3%), and the fourth group received the diet with coriander seed of 3%, respectively. Different levels of coriander seed in experimental diets were replaced by Alfa alfa. It is worth noting that each ingredient was weighed daily and fed separately to each lamb in individual stands. Feed was offered for ad libitum intake throughout the experiment. Coriander seed was mixed with the concentrate mixture in the experimental group of the lambs.

Table 1. Components of experimental diets and the proportion of different nutrients (percentage of dry matter).

Diet items	Treatment			
	Control	1	2	3
Coriander seed	0	1	3	5
Corn	25	25	25	25
Alfa alfa	30	29	27	25
Barley	22.5	22.5	22.5	22.5
Soybean meal	15	15	15	15
Sugar beet molasses	5	5	5	5
Salt	0.5	0.5	0.5	0.5
Mineral Supplements	0.5	0.5	0.5	0.5
Vitamin supplements [®]	0.5	0.5	0.5	0.5
Sodium Bicarbonate	0.5	0.5	0.5	0.5
Limestone	0.5	0.5	0.5	0.5
Nutrients				
Dry matter metabolizable energy (Mkal Kg ⁻¹)	2.45	2.47	2.47	2.44
Protein (%)	16.23	16.10	16.10	16.00
Calcium (%)	0.641	0.750	0.750	0.657
Phosphorus (%)	0.427	0.435	0.435	0.448

[®]Each kg of vitamin supplements contains 600,000 IU of beta-carotene, 200,000 IU of cholecalciferol, 200 mg of tocopherol, 2500 mg of antioxidant, 195 grof calcium, 80 grof phosphorus, 210000 mg of magnesium, 2200 mg of Manganese, 3000 mg of iron, 300 mg of copper, 300 mg of zinc, 100 mg of cobalt, 120 mg of iodine and 1.1 mg of selenium.

Evaluated parameters

Performance and feed efficiency

Individual weighing was fulfilled every subsequent 30 d in the morning after fasting (feed and water), so that 14 hours of starvation was taken into accounts. Quantity of feed offered were recorded, and daily Feed intake was calculated monthly (three times in total). Mean daily weight gain and feed conversion ratio were calculated at the end of trial.

Digestibility

Digestion trial consisted of 7 d for diets adaptation and 5 d feces collection period. During the collection period, total feces were collected. Feces collection was performed directly from the rectum and the daily fecal collections were weighed and mixed thoroughly by hand at the end of each day. Feces samples immediately transferred to the refrigerator at -4°C.

Obtained samples of each daily collection of diets and feces were pre-dried in drying oven at 60 to 65°C for 48h. A certain amount of each sample was placed in plastic. The apparent nutrients digestibility including crude protein, ash, crude fiber, neutral and acidic insoluble fiber, crude fat (ether extract) was determined using the acid insoluble ash (AIA) marker. Formula based on AIA were as:

$$\text{Dry matter Digestibility (\%)} = 100 - \left(100 \times \frac{\text{AIA in diet}}{\text{AIA in feces}}\right)$$

$$\text{Nutrient Digestibility (\%)} = 100 - \left(100 \times \frac{\text{AIA in diet}}{\text{AIA in feces}} \times \frac{\text{Nutrient in feces}}{\text{Nutrient in diet}}\right)$$

Materials in whole ash were boiled with dilute solution of hydrochloric acid and minerals remained in acidic solution and on the filter paper will be considered as acid-insoluble ash, mainly comprising silica.

Blood metabolites and immune system parameters

Blood samples (10 cc) were obtained monthly from the jugular vein of each lamb before the morning feeding and at the beginning (day 97), mid (day 142) and end of the period (day 187). Blood samples were collected into serum separator tubes and centrifuged (3000 rpm 10 min.⁻¹). These parated serum was stored at -45°C until analyzed. Analysis of cholesterol, triglycerides and creatinine were based on Pars Test kits and the biochemical kits (Randox, UK. Company) used for non-esterified fatty acids and beta-hydroxybutyric acid. The parameters were measured by automated analyzer (Technicon RA). White blood cells and whole blood cells were counted in lymphocytes and eosinophil cells.

Rumen parameters

Samples of the rumen fluid were collected before the morning feeding and 2 and 4h after feeding using vacuum and gastric tube (50 mL). The first rumen fluid sample was discarded to remove the effect of saliva. Immediately pH was measured potentiometrically using a portable pH meter (Testo Model 230), using 4 layers of confluent rumen fluid filtered with 20% metaphosphoric acid (m-HPO₃) at a ratio of five to one (five milliliters). Ruminal fluid and 1 mL of metaphosphoric acid were mixed in 15 mL Falcon tubes and stored at -20°C during testing and after freeze-thawing at refrigerator temperature (using a model refrigerated centrifuge (Sigma-2). -16-P-Germany) centrifuged for 10 min (4000 rpm)). Dissolved sections in 1.5 mL plastic micro tubes were used to determine volatile fatty acids, then 2-ethylbutyric acid was added as an internal standard and stored at -20°C until using. Acetic, propionic, butyric acids were measured by gas chromatography (GC) method (model NHP6890 equipped with isothermal oven, DB-1701 column, 0.25 mm 25 0.25 mm 30 30 mm) (Length, Internal Diameter of Film Condition, respectively) and FID type detector, helium carrier gas (1 mL min.⁻¹), column temperature and detector were measured at 200 and 25°C, respectively. Determining ammonia nitrogen concentration, rumen fluid was equilibrated with 0.2ND (5 mL rumen fluid and 5 mL hydrochloric acid) in 15 mL falcon tubes and centrifuged (4000 rpm). The leachate was used for determination of ammonia nitrogen and stored at -20°C. Finally, the ammonia nitrogen concentration was calculated by phenol-hypochlorite method (Broderick & Kang, 1980).

Carcass performance

The number of 8 lambs (two replicates per litter) were selected and slaughtered after 14 hours of starvation. The slaughter was done with stunning by cerebral concussion and cutting the jugular veins and carotid arteries. Full and empty digestive compartments (rumen/reticulum, omasum, abomasum, small intestine and large intestine) were removed and weighed. The difference between full and empty compartments was considered as weight of gut content. This was used to get the determination of empty body weight. Therefore, the hot carcass weights were recorded. Then, carcasses were cooled for a period of 24 hours in 2 and 4°C and the cold carcass weight was achieved. Thus, weight loss due to cooling could be calculated.

Chemical composition of meat

After slaughtering, samples were taken to measure qualitative parameters of meat and fatty acids composition from three parts of the thigh, head and shoulders, and physical and chemical characteristics of meat and approximate decomposition (Fat, crude protein, ash, and moisture content) were measured using the AOAC (2000) standard.

Statistical analysis

The SAS package was performed for statistical analyses (version 9.1) (Statistical Analysis System [SAS], 2003). Analysis of variance (ANOVA) was used by a GLM procedure for all the characters. Also, the one-way ANOVA based on a completely randomized design was used to test the effect of diet on evaluated parameters including carcass, immune system, blood metabolites, rumen parameters and meat quality characteristics. The level of significance was set at 0.05. The mean for treatments were compared by Duncan statistical test. The model was as follow:

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

where: Y_{ij} was the value of each observation, T_i : The effect of the experimental treatment and: e_{ij} random error.

Results

The effect of dietary coriander seeds on performance of Sanjabi lambs is presented in Table 2. Adding coriander seeds make a significant increase for feed intake ($p < 0.05$). Also, the significant increase was achieved for daily weight gain. Dietary coriander seeds in 3 and 5% reduced feed conversion ratio in compare to control. In other words, when the 5% coriander seeds used, feed conversion ratio was increased in compare to control group but not significant. Dry matter intake was significantly increased by adding coriander seeds, linearly. There was no significant difference for apparent digestibility of crude protein, crude fat, neutral and acidic detergent fiber, and crude ash ($p > 0.05$). Compared to the control treatment, dietary coriander seed had significant effect on the apparent digestibility of calcium and phosphorus ($p < 0.05$).

Table 2. Effect of Dietary coriander seeds on performance and digestibility in Sanjabi lambs.

Parameter	Treatment ^y				SEM	P-Value
	Con ^e	1	3	5		
performance						
Feed intake (gr d ⁻¹)	1185.55b	1498.86a	1494.37a	1488.53	40.57	0.001
Daily weight gain (gr d ⁻¹)	228.70b	299.58a	298.15a	265.83	11.87	0.046
Feed Conversion Ratio	6.01	5.50	5.70	6.34	0.25	0.612
Digestibility						
Dry matter intake (%)	83.56b	84.86a	85.85	86.04a	0.51	0.061
Crude protein (%)	76.96	77.69	77.76	75.17	1.14	0.667
Crude fat (%)	76.58	77.93	78.56	75.43	1.28	0.742
Neutral detergent fiber (NDF) (%)	65.19	58.04	57.15	59.50	2.20	0.424
Acid detergent fiber (ADF) (%)	50.13	49.76	48.88	45.96	2.56	0.782
Ca (%)	37.30c	53.98a	54.15	44.21ab	2.99	0.069
P (%)	50.66b	65.65a	66.73	53.61b	2.61	0.033
Ash (%)	55.10	62.31	61.45	60.02	1.61	0.198

^yMeans within rows with different superscript are significantly different at p < 0.05. No superscript means there is no significant difference. ^eCon: Control; 1: 1% coriander seed, 3: 3% coriander seed; 5: 5% coriander seed.

In this study, changes in the amount of white blood cells in response to anthrotoxia vaccine were evaluated (Table 3). The results showed that dietary coriander seeds had a significant effect on neutrophils, lymphocytes, monocytes and eosinophil’s cells, in 7 and 14 days after slaughtering. On day 21 after anthrotoxia vaccine injection, neutrophil cells decreased (5% dietary coriander seed) in compared to control.

Table 3. Effect of Dietary *Coriandrum sativum* seeds on white blood cells in Sanjabi lambs.

Days after Enterotoxaemia vaccine	Parameter	Treatment ^y				SEM	P-Value
		Con ^e	1	3	5		
7	Neutrophil	40.80	47.66	43.50	44.43	3.73	0.779
	Lymphocyte	59.00	52.00	56.33	53.53	3.78	0.776
	Monocyte	0.20	0.33	59.00	23.30	0.12	0.577
	Eosinophil	0.00	0.00	0.16	0.00	0.05	0.427
14	Neutrophil	55.66	51.66	47.66	43.35	2.23	0.366
	Lymphocyte	44.00	48.33	52.33	42.44	2.22	0.331
	Monocyte	0.33	0.00	0.00	0.00	0.11	0.391
	Eosinophil	0.00	0.00	0.00	0.00	0.00	0.000
21	Neutrophil	41.50	25.00	39.50	33.33	3.22	0.065
	Lymphocyte	58.00	74.33	60.50	22.23	3.13	0.063
	Monocyte	0.00	0.00	0.00	0.00	0.00	0.000
	Eosinophil	0.50	0.66	0.00	0.00	0.00	0.000
35	Neutrophil	47.83	46.00	49.00	44.00	1.80	0.821
	Lymphocyte	51.33	45.00	50.66	48.00	2.01	0.807
	Monocyte	0.00	0.00	0.00	0.00	0.00	0.000
	Eosinophil	0.00	0.00	0.00	0.00	0.11	0.427
42	Neutrophil	47.83	46.00	49.00	48.01	1.80	0.821
	Lymphocyte	51.33	54.00	50.66	53.06	2.01	0.807
	Monocyte	0.00	0.00	0.00	0.00	0.00	0.000
	Eosinophil	0.00	0.00	0.33	0.00	0.11	0.427

^yMeans within rows with different superscript are significantly different at p < 0.05. No superscript means there is no significant difference. ^eCon: Control; 1: 1% coriander seed, 3: 3% coriander seed; 5: 5% coriander seed.

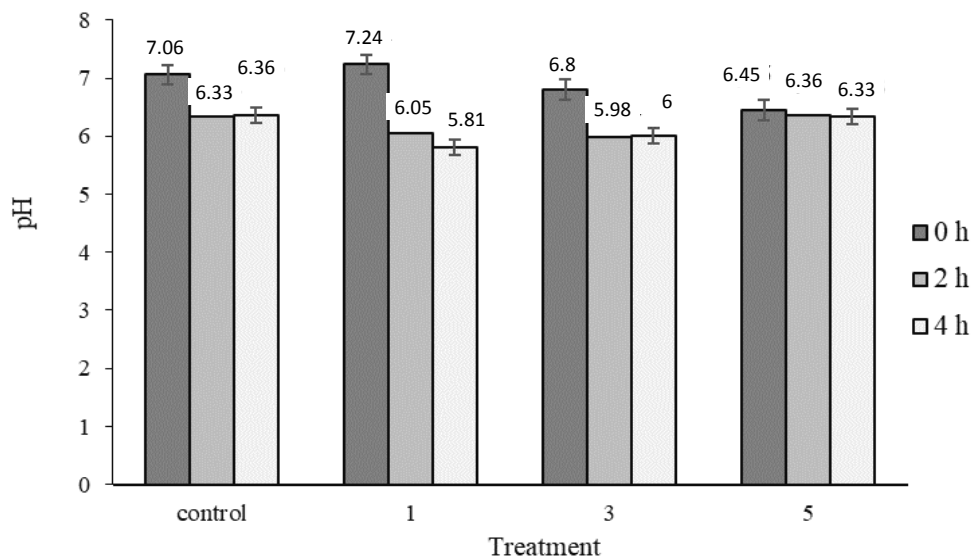
Table 4 shows the effect of dietary coriander seeds on blood parameters in Sanjabi lambs. The creatinine and unesterified fatty acids increased at the beginning of the period, but not differed from control (p > 0.05). Albumin, total globulin, glucose, total protein, cholesterol, triglyceride, urea, β-Hydroxybutyric acid, aspartate transaminase and alanine transaminase were not affected by diets supplemented with coriander seeds (p < 0.05). At the middle of trial, the metabolites concentration changed significantly compared to the early of trial. This can be implemented to glucose and triglyceride levels, which increased significantly by 5% dietary coriander seeds. Urea was lower by 5% dietary coriander seeds than control (p < 0.05). At the end of period, cholesterol was decreased by 5% dietary coriander seeds.

Table 4. Effect of Dietary *Coriandrum sativum* seeds on blood parameters in Sanjabi lambs.

Parameter	d	Treatment ^y				SEM	p - value
		Con ^e	1	3	5		
Albumin (gr dL ⁻¹)	142	3.64	3.62	3.68	3.69	0.029	0.723
	187	3.64	3.64	3.76	3.67	0.040	0.406
Total globulin (mg dL ⁻¹)	142	2.64	2.52	2.70	2.59	0.061	0.507
	187	2.74	2.40	2.62	2.63	0.071	0.144
Glucose (mg dL ⁻¹)	142	73.40b	87.00a	72.40b	86.37a	2.09	0.000
	187	87.00	88.80	90.00	87.00	1.300	0.673
Total protein (mg dL ⁻¹)	142	6.28	6.14	6.38	6.46	0.064	0.326
	187	6.38	6.04	6.38	6.36	0.088	0.203
Cholesterol (mg dL ⁻¹)	142	48.80	45.00	43.40	44.30	2.180	0.313
	187	60.40	42.60b	50.60a	44.00a	3.180	0.061
Triglyceride (mg dL ⁻¹)	142	6.90	11.20b	8.40a	12.00ab	0.766	0.053
	187	12.20	9.20	11.30	11.00	0.871	0.381
Creatinine (mg dL ⁻¹)	142	1.01	0.988	1.05	1.96	0.019	0.423
	187	1.13	1.15	1.15	1.00	0.019	0.882
Urea (mg dL ⁻¹)	142	50.78	38.60b	54.06a	48.36a	2.330	0.005
	187	44.72	37.13	42.50	40.00	1.510	0.102
Unesterified fatty acids (mmol L ⁻¹)	142	0.35	0.32	0.31	0.45	0.020	0.755
	187	0.39	0.32	0.37	0.39	0.016	0.256
β -Hydroxybutyric acid (mg dL ⁻¹)	142	0.35	0.37	0.32	0.44	0.025	0.798
	187	0.47	0.31	0.41	0.45	0.033	0.143
Aspartate transaminase (IU L ⁻¹)	142	83.00	71.20	90.60	85.86	4.62	0.238
	187	0.02	0.05	0.03	0.04	0.006	0.105
Alanine transaminase (IU L ⁻¹)	142	10.20	9.60	11.00	11.05	0.520	0.581
	187	15.60	12.60	13.20	16.00	0.952	0.427

^yMeans within rows with different superscript are significantly different at $p < 0.05$. No superscript means there is no significant difference. ^eCon: Control; 1: 1% coriander seed, 3: 3% coriander seed; 5: 5% coriander seed.

The results for rumen parameters are shown in Figures 1 and 2. There was no significant difference for rumen fluid pH at 0, 2 and 4h after feeding ($p > 0.05$). However, pH was decreased by dietary coriander seeds in compared to control. Diet supplemented by coriander seeds reduced ammonia nitrogen and there have not seen a difference for times considered.

**Figure 1.** Effect of Dietary *Coriandrum sativum* seeds on rumen pH in Sanjabi lambs (before the morning feeding and 2 and 4h after feeding).

In Table 5, effect of dietary coriander seeds on carcass in Sanjabi lambs is presented. Dietary coriander seeds (5%) made a significant increase for live weight, skin weight, Slim weight, and rumen capacity in compared to control ($p < 0.05$). Hot and cold carcass weight, intra-abdominal fat, heart and lung weights were increased compared to the control ($p < 0.05$). Also, heart, kidney, liver, spleen and Gastrointestinal full weight increased linearly compared to the control group.

In Table 6, effect of dietary coriander seeds on meat composition of Sanjabi lambs is presented. Meat dry matter, ash, crude protein and fat were not affected by dietary coriander seeds ($p < 0.05$). The effect of dietary coriander seeds on meat color in Sanjabi lambs is shown in Table 7. Dietary coriander seeds made a significant different for L and b parameters. Hence, by adding coriander seeds, L and b parameters were

decreased. There was not seen any significant difference for a, C and H parameters ($p > 0.05$). The meat's fatty acid profile of Sanjabi lambs fed diets supplemented by coriander seed is shown in Table 8. Meat fatty acid profile were not affected by dietary coriander seed ($p > 0.05$). Linoleic and linolenic acids were higher in lambs' meat received coriander seed than the control group.

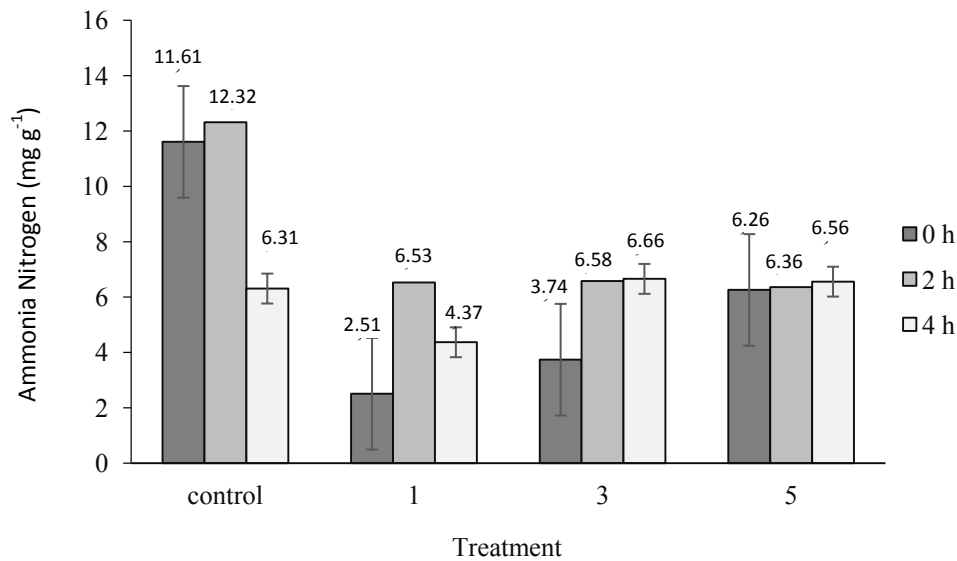


Figure 2. Effect of Dietary *Coriandrum sativum* seeds on rumen Ammonia Nitrogen (mg dL⁻¹) in Sanjabi lambs (before the morning feeding and 2 and 4h after feeding).

Table 5. Effect of Dietary *Coriandrum sativum* seeds on carcass in Sanjabi lambs.

Parameter	Treatment [‡]				SEM	p - Value
	Con [€]	1	3	5		
Live weight (gr)	50489.62	51262.33	50296.45	52969.26	1361.40	0.000
Carcass weight (hot) (gr)	19843.37b	21916.67a	20790.00a	22695.96	585.94	0.002
Carcass weight (cold) (gr)	19300.00b	21901.67a	20120.00a	22396.75	574.92	0.002
Carcass efficiency (%)	43.24	43.50	42.47	44.62	0.455	0.200
Head weight (gr)	2308.33	2320.00	2185.00	2396.00	74.25	0.767
Head percent (%)	11.63	9.69	9.59	9.68	0.46	0.189
Hand and feet weight (gr)	1036.67	1278.33	1090.00	1136.00	29.34	0.187
Hands and feet percent (%)	2.32	2.18	2.15	2.13	0.47	0.421
Skin weight (gr)	4730.00c	5893.33a	5368.33ab	5469.46	196.93	0.019
Intra-abdominal fat (gr)	790.00b	771.00b	825.00a	625.00	53.81	0.049
Liver weight (g)	790.00	888.33	970.00	986.00	43.48	0.265
Liver percentage (%)	3.99	3.79	4.26	4.36	0.182	0.641
Spleen weight (g)	130.00	85.00	155.00	136.00	20.17	0.369
Spleen percentage (%)	0.51	0.36	0.68	0.69	0.092	0.424
Heart Weight (g)	166.66b	195.00a	195.00a	202.00	6.148	0.069
Heart percentage (%)	0.84	0.83	0.85	0.86	0.038	0.912
Lung Weight (gr)	445.00b	591.66a	566.66a	601.45	534.44	0.034
Lung percentage (%)	2.24	2.52	2.48	2.52	0.082	0.385
Gastrointestinal full Weight (gr)	4406.66	5336.66	5308.33	5960.29	232.46	0.184
Gastrointestinal empty Weight (gr)	998.33	1190.00	1128.33	1350.00	51.54	0.343
Slim Weight (gr)	3741.67c	6065.99a	5378.33ab	6950.00	432.53	0.049
Back fat thickness (cm)	4.13	4.13	4.53	4.36	0.156	0.425

[‡]Means within rows with different superscript are significantly different at $p < 0.05$. No superscript means there is no significant difference. [€]Con: Control; 1: 1% coriander seed, 3: 3% coriander seed; 5: 5% coriander seed.

Table 6. Effect of Dietary *Coriandrum sativum* seeds on meat chemical composition of Sanjabi lambs.

Parameter (%)	Treatment [®]				SEM	p - Value
	Con [€]	1	3	5		
Dry matter	25.97	25.94	27.19	27.19	0.32	0.240
Protein	21.21	21.24	21.35	21.35	0.19	0.960
Ash	1.22	1.32	1.47	1.47	0.08	0.610
Fat	3.09	2.46	2.96	2.96	0.25	0.580

[®]Means within rows with different superscript are significantly different at $p < 0.05$. No superscript means there is no significant difference. [€]Con: Control; 1: 1% coriander seed, 3: 3% coriander seed; 5: 5% coriander seed.

Table 7. Effect of Dietary *Coriandrum sativum* seeds on meat color in Sanjabi lambs.

Parameter	Storage time (°C)	Treatment ^y			
		Con ^e	1	3	5
L	0	41.12	41.32	40.30	42.32
	4	45.12	43.00	41.07	43.42
	7	47.12	43.12	43.37	43.44
a	0	15.10	14.12	14.90	15.15
	4	14.50	14.01	14.44	15.96
	7	8.14	7.23	7.35	8.13
b	0	2.94	2.39	2.86	3.28
	4	7.43	7.63	7.46	8.35
	7	9.53	9.57	9.32	9.96
C	0	15.32	14.15	15.01	15.75
	4	16.17	16.34	16.20	16.87
	7	12.21	12.13	12.00	12.96
H	0	10.10	10.21	8.43	9.09
	4	28.41	28.10	27.36	27.65
	7	47.30	53.32	52.60	53.32

^yMeans within rows with different superscript are significantly different at $p < 0.05$. No superscript means there is no significant difference. ^eCon: Control; 1: 1% coriander seed, 3: 3% coriander seed; 5: 5% coriander seed.

Table 8. Effect of Dietary *Coriandrum sativum* seeds on meat fatty acid profile in Sanjabi lambs.

Parameter	Treatment ^y				SEM	p - value
	Con ^e	1	3	5		
C10:0	0	0	0	0	0	0
C12:0	0.28	0.12	0.02	0.06	0.08	0.500
C14:0	3.29	3.35	3.25	3.75	0.17	0.976
C14:1	2.09	2.73	2.84	2.96	0.18	0.223
C16:0	20.55	20.93	21.21	22.27	20.90	0.593
C16:1	4.43	4.39	4.33	4.49	0.19	0.979
C18:0	12.32	12.09	11.31	12.58	0.25	0.244
C18 :1	36.13	33.57	36.81	38.69	0.83	0.253
C18:2	11.48	13.96	11.63	12.68	0.74	0.325
C18:3	1.09	1.15	0.97	1.09	0.08	0.680
Saturated fatty acid	37.80	38.37	36.98	37.85	0.66	0.746
Unsaturated fatty acid	53.85	53.72	57.72	58.00	0.01	0.127
Ratio of Saturated/ Unsaturated fatty acid	0.70	0.71	0.64	0.77	0.01	0.267

^yMeans within rows with different superscript are significantly different at $p < 0.05$. No superscript means there is no significant difference.

^eCon: Control; 1: 1% coriander seed, 3: 3% coriander seed; 5: 5% coriander seed.

Discussion

Performance and digestibility

Based on the results, increased feed intake can be attributed to physical shape of coriander seed, implemented to digestibility process and passage rate of nutrients. On the other hands, linalool content of coriander seed made increased feed intake, changing rumen microbial content being as secondary importance. These results were in accordance with those reported by Yang, Ametaj, Benchaar and Beauchemin (2007) but not in agreement with the results of Mohammed et al. (2018). The effect of the use of the essential oil on the conversion ratio was not in agreement with the results of this study, due to differences in the variety of the medicinal plant, the concentration of active ingredients and the climatic conditions of the growing area of the medicinal plant. As pointed out by Seifzadeh, Farzad, Hossein, Jamal and Bahman (2016), increasing feed intake may elevate digestion coefficient. Seifzadeh et al. (2016) showed that herbal additive in calves ration had significant effect on ADF and NDF digestibility in which NDF and ADF were increased.

White blood cells

In the current study, dietary coriander seeds made a significant effect on neutrophils, lymphocytes, monocytes and eosinophil's, in 7 and 14 days after slaughtering. It may due to the sterol and tocopherol compounds that coriander seeds contain. The sterol and tocopherol compounds have anti-oxidant ability

which suppress the free radicals (Burdock & Carabin, 2009). The immune system could also amplified by the presence of volatile fatty acids in Coriander seeds (Moriguchi & Muraga, 1999). Our results were in accordance with those reported by Al-Zwein (2011), Ibrahim (2013), and Mohammed et al. (2018). Yang et al. (2010) showed that adding cinnamaldehyde, garlic and mulberry essential oil to dairy cattle diet had no significant effect on total white blood cell count and overall immune system of dairy cows which did not match our results. Moriguchi and Muraga (1999) showed that dietary coriander seeds affect the immune system, improving white blood cells count. The findings were observed on Awassi sheep fed by three levels of coriander feed (0, 2.5 and 5%) in which white blood cells increased. Our results were consistent to what has been found by Moriguchi and Muraga (1999) and Mansour, Adnan, & Nader (2013).

Blood parameters

We showed that blood parameters including albumin, total globulin, glucose, total protein, cholesterol, triglyceride, urea, β -Hydroxybutyric acid, aspartate transaminase and alanine transaminase were not affected by diets supplemented with coriander seeds. It is necessary to mention aspartate transaminase and alanine transaminase tended to be increased by the adding 5% Coriander seed. It may reduce the toxic effects from saponins and other antifouling substances. By increasing secondary metabolites of medicinal plants, the liver enzymes did not increase significantly. On the other hands, decreased cholesterol-synthesizing enzyme activity in the liver reduces tissue cholesterol, reducing the ratio of unsaturated to saturated fatty acids by aging (Nute et al., 2007). Also, coriander oil possesses antimicrobial properties against pathogenic and saprophytic microorganisms, having positive effect on health and performance (Çabuk, Alçiçek, Bozkurt, & Imre, 2001). Our results were in accordance with those reported by Khamisabadi, Kafilzadeh and Charaïen (2016). Who mentioned that concentrations of cholesterol, nonesterified fatty acids (NEFA), beta-hydroxybutyric acid (BHBA), blood creatinine levels were not influenced by addition of either thyme or peppermint to the diet. While triglyceride, glucose and urea were significantly lower in lambs received these plants in their diets. Also, Hosoda, Kuramoto, Eruden, Nishida, and Shioya (2006) has shown that concentrations of glucose, triglyceride, NEFA, total protein, in plasma were unaffected by peppermint treatments (5% of the diet on a dry matter basis) in holstein steers.

Rumen parameters

No significant effect was observed for rumen pH and ammonia nitrogen of lambs. By adding coriander seed, rumen pH was reduced but not significant. Reduced pH is from increased fatty acids by adding coriander seeds. As pointed out by Chaves et al. (2008), using essential oils, cinnamaldehyde, had no effect on rumen pH which is in accordance with our results. Also, Benchaar, McAllister and Chouinard (2008) in dairy cow and Yang et al. (2010) in beef cattle reported no change on ruminal pH when the diet was supplemented by cinnamaldehyde. There was no significant difference for diets supplemented by coriander seeds for ammonia nitrogen. Also, there have not seen a difference for times considered. These results are in agreement with those reported by Agle et al. (2010) and Aguerre, Wattiaux, Powell, Broderick and Arndt (2011) who reported that the difference in the ration (with and without essential oils) had no significant effect on ammonia nitrogen. It has been documented that coriander seed have the antimicrobial effect by linalool content, removing harmful microorganisms of (Evans & Martin, 2000), reducing ammonia nitrogen in the rumen. Jahani-Azizabadi, Danesh Mesgaran, Vakili, Rezayazdi and Hashemi (2011) reported a decrease in ammonia nitrogen by using thyme, cinnamon and clove essential oils at dose 1 $\mu\text{L mL}^{-1}$ of culture fluid in a 24h batch culture study. Also Benchaar et al. (2008) observed ammonia nitrogen of ruminal fluid of dairy cows was not affected by using 0.75 or 2 g d^{-1} of a mixture of essential oil compounds. The incompatibility between the current study with others in vivo observation may be attributed to different experimental diet, doses of compounds used and experimental conditions.

Carcass performance

Carcass performance was significantly improved by using coriander seed. Özdoğan, Önenç and Önenç (2011) reported that there is no significant effect for carcass performance by using essential oils. In rabbits, Abd El-Hady, El-Ghalid, and El-Raffa (2013) showed a significant effect of using coriander seed on carcass performance which is inconsistent with our results. Shahabi and Chashnidel (2014) showed that canola oil made a significant increase for carcass attributes including carcass and feet weights. Coriander seed

components can be present the intestinal health which enhances availability of essential nutrients for absorption, therefore, animal growth performance and consequently carcass performance could be improved (Franz, Baser and Windisch, 2010). On the other hands, increased enzyme activity following intestinal health resulted in a better nutrient absorption (Franz et al., 2010). Moreover, the effectiveness of essential oil on carcass performance could also depend on the basal diet composition, feed intake level and environmental conditions (Abd El-Hady et al., 2013). As pointed out by Yusuf, Goh, Samsudin, Alimon, & Sazili (2014), goats fed *Andrographis paniculata* produced higher meat yield and relatively lower fat contents. They concluded that higher lean and muscle proportion are achieved by more efficient digestion of nutrients. Decreasing fats contents was occurred by dietary *Andrographis paniculata* which improved rumen fermentation processes and efficient digestive function. Our results were in accordance with those reported by Hassan, Hassan & Al-Rubeii (2010) in Karadi lambs fed by *Nigella sativa*. Hassan et al. (2010) showed that the heavier slaughter weights, cold carcass and fat tail weights were associated with lambs fed highest level of rumen degradable nitrogen supplemented with *Nigella sativa*. But they also reported a linear increase in fat-tail weight associated with lambs fed increasing levels of rumen degradable nitrogen supplemented with *Nigella sativa*.

Meat quality

A well source of animal protein is ruminant meat which is valued in many cultural culinary traditions. In recent years, consumers' choice is to reduce the composition and quality of fat and high quality of meat. Therefore, improve the safety, nutritional and sensory quality of ruminant meat is of ongoing interest and it have been the subject of research in recent times. Meat chemical composition of Sanjabi lambs was not affected by dietary coriander seed. These results were in agreement with those obtained by Smeti, Atti, Mahouachi, and Munoz (2013), who reported that Rosemary essential oils had no significant effect on the meat chemical composition of lambs. This is also confirmed by Zhang, Yan, Keen and Waldroup (2005) in broilers, who had used essential oil mixture in the ration. Similarity in meat chemical composition of lambs may be from feeding system and animal's slaughter weight of (Smeti, Hajji, Mekki, Mahouachi, & Atti, 2017). Lightness and yellowness parameters of meat were affected by dietary coriander seeds. The difference between lightness values could be explained by the fat composition of meat. Our results was disagree with the results of O'Grady, Maher, Troy, Moloney and Kerry (2006), who concluded that rosemary extract dietary supplementation to cattle did not significantly improve the meat color. Our results showed that fatty acid profile were not affected by the coriander seed presence in the diet despite the fact that they tended to be increased in compare to the control. Chaves et al. (2008), reported that fatty acid profile of liver and back fat was not modified by essential oil supplementation which is in accordance of the results. On the other hands, Vasta et al. (2013), reported that the supplementation of artemisia essential oil affected lamb meat fatty acid profile. The ability of ruminal microorganisms to adapt to essential oil intake and/or modified the chemical structure of some terpenoids is the reason of the lack of essential oil supply effects on fatty acid profile (Malecky & Broudiscou, 2009). Odhaib, Adeyeme and Sazili (2018) showed that dietary supplementation of *Nigella sativa* seeds and *Rosmarinus officinalis* leaves had beneficial effects on meat quality in Dorper lambs in which dietary supplementation of medicinal plants reduced lipid oxidation. The reason could be attributed to the presence of polyphenols in the medicinal plants.

Conclusion

It can be concluded that supplementation of coriander seeds up to 5% in the diet did not change apparent digestibility of crude protein, crude fat, neutral and acidic detergent fiber, crude ash, rumen fluid pH and ammonia nitrogen at 0, 2 and 4h after feeding, Meat dry matter, ash, crude protein and fat, and the meat's fatty acid profile. On the other hands, we showed a significant effect of dietary coriander seeds for feed intake, blood cells of 7 and 14 days after slaughtering, blood metabolites concentration at the middle of trial, and L and b parameters of meat. Based on the results, future studies can be focused on the investigation of higher percentage of coriander seeds or powder.

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