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Effects of Feeding Hemp Seeds on Growth Performance and Carcass Characteristics of Fattening Lambs with Low Crude Protein Diets

Research Article

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ABSTRACT

In order to evaluate the effects of full-fat hemp seeds (HS) and dietary crude protein (CP) level on performance, and carcass characteristics, 30 Baluchi male lambs, were divided into three groups as follows: 1) lambs fed a diet with 14% CP without HS (CON), 2) lambs fed a diet with 14% CP containing 10% HS (HPHS), and 3) lambs fed a diet with 12% CP containing 10% HS (LPHS). Lambs were placed in individually pens and adapted to the diets for 21 days before starting the 84-day experimental period. On the final day of the experiment, all the animals were slaughtered and the carcass data was recorded. Results showed that the lambs receiving HPHS diet had significantly higher dry matter intake (DMI), daily weight gain (DWG), final body weight, warm carcass weight, and fat-tail weight compared to other groups (P<0.05). In contrast, feed conversion ratio was significantly improved by HS feeding (P<0.05). A significant increase for cold carcass, carcass lean meat, brisket and brisket lean meat was observed for HPHS diet (P<0.05). With the addition of HS to diet, a significant increase was observed in the weight of fat-tail, shoulder, shoulder lean meat and visceral fat (P<0.05). The results showed that, addition of HS to the diet of fattening lambs improved growth and carcass performance and by replacing 10% of the diet of fattening lambs with HS, it is even possible to reduce the CP level of the diet by about 2%.

KEY WORDS carcass characteristics, fattening lamb, growth performance, hemp seeds.

INTRODUCTION

Nowadays, the highest costs in livestock production are related to feed, with protein sources being the most expensive component. Additionally, the high and variable price of soybean meal has led to its replacement with alternative protein sources for livestock (Vasta *et al*. 2008). In recent researches, alternative feeds have been used in animal diets to replace soybean meal as a source of protein, one of which is hemp seeds (HS). Industrial hemp (*Cannabis sativa*) and marijuana are different varieties of the same species. Although they are identical in appearance, they differ significantly in their psychoactive substance content (Hazekamp *et al*. 2010).

Hemp plant is believed to have originated in Central Asia, and historically, it has played a significant role in food production and medicine (Van Bakel *et al*. 2011). It has been produced worldwide for centuries as it can be grown in most climatic conditions (Johnson, 2018). The seeds of hemp are obtained from hemp-related industries and can be a wonderful source of protein and oil in animal nutrition (Mierlita, 2016). On average, HS contains 25-35%

oil, 20-25% crude protein (CP), and 20-30% carbohydrates (Callaway, 2004; Mierlita, 2016). The oil in HS is constituted mostly by polyunsaturated fatty acids (Mierlita, 2018). Albumin and Edestin are the two main proteins in HS and both are rich in the amino acids (Callaway, 2004). The amino acid profile of HS is very favorable, with a high availability in the small intestine, because it has a lower degradability in the rumen than other protein sources (i.e. soybean meal, etc.) commonly used in ruminant diets (Mustafa *et al.* 1999). In addition to protein and fat, HS contains a small amount of digestible carbohydrates and vitamins B, C, E, and D (Callaway, 2004).

Accordingly, it is assumed that supplementing HS in the diet of fattening lambs could reduce the feed cost by reducing the CP level of the diet without affecting the animal performance. Although there have been reports, the inclusion of HS has not been widely studied in conjunction with a reduction of CP (Mustafa *et al.* 1999; Gibb *et al.* 2005; Dayani *et al.* 2011; Turner *et al.* 2012). Therefore, the aim of the present study was to investigate the effects of supplementing the diet with HS and different CP levels on growth performance, carcass characteristics, and haemato-chemical parameters of fattening male lambs.

MATERIALS AND METHODS

Animals, experimental design and diets

This trial was conducted in the research farm of Shahid Bahonar University of Kerman, Iran. Hemp seeds were obtained from hemp farms in Fars province of Iran and their chemical compositions were determined (AOAC, 2005). The chemical composition of full-fat HS is shown in Table 1. In this experiment, thirty Baluchi male lambs, homogeneous for age (6±0.5 months) and weight (24±1.5 kg), were randomly divided in three groups according to completely randomized design. The experimental treatments included: 1) lambs fed a diet with 14% CP without HS (CON), 2) lambs fed a diet with 14% CP containing 10% HS (HPHS), and 3) lambs fed a diet with 12% CP containing 10% HS (LPHS). The experimental diets were balanced based on different amounts of HS (0 and 10%) and CP levels (14 and 12%) according to the NRC (2007) recommendations (Table 1).

Lambs were placed in individually pen (100×200 cm), with a cement floor, proper ventilation and sufficient feeding and watering devices, and were deparasitized and vaccinated against enterotoxaemia. Fresh and clean water was available all the time. All groups were fed a total mixed ration (TMR) twice a day at 08:00 and 17:00 *ad-libitum*. Lambs were adapted to the diets and pens for 21 days before starting the 84-day experimental period. All animal husbandry procedures were approved by Animal Care and Use Committee of Shahid Bahonar University of Kerman according to EU standards (Approval No. 1284130).

Data collections

Dry matter consumed by each lamb was measured using the daily feed provided and the average remaining feed during the entire rearing period. To weigh the animals at the end of each week, the feed was removed at 05:00 a.m. and the body weight (BW) of the animals was recorded at 08:00 a.m. The daily weight gain (DWG) was obtained as the difference between the initial and final weights over the interval of the performance phase (84 d). The feed conversion ratio (FCR) was calculated by dividing the dry matter intake (DMI) by the weight gain. On the last day of the experiment (day 84), 2 h before morning feeding, 10 mL blood samples were taken with a special tube from the jugular vein of the lambs. To obtain serum, the blood samples were kept at environmental temperature for 25 min, then the samples were centrifuged at 1500 × g for 10 minutes, and the serum was kept at -20 ºC until transfer to the laboratory (Dayani *et al.* 2011). Fasting blood glucose (FBS), total protein, albumin, creatinine, and urea-N concentration were determined by laboratory kits (Pars Azmoon Co., Iran) by use of AUTOLAB auto-analyzer set (model PM4000, AMS Co. Romania). Total cholesterol, high-density lipoproteins (HDL), and triglycerides (TG) were measured using enzymatic colorimetric test and adsorption at 500 nm was recorded by spectrophotometer (Model 6300, Jenway Co., UK) using a monoreagent kit (kits: CHOD, GPO-PAP and HDL-kit, Pars Azmoon Co., Iran).

On the last day of the trial, the lambs were taken to the slaughterhouse and were Muslim slaughtered after 18 h of fasting. After slaughter, the head was separated from the atlas joint and they were pelted (Dayani *et al.* 2011). The weights of warm carcass, offal parts, and components of the digestive tract were recorded. The dressing percentage was measured based on the following equation (Dayani *et al.* 2011):

Dressing percentage (%)= (warm carcass weight (kg) / final live BW (kg)) × 100

The carcasses were kept in the refrigerator at 4 ˚C for 24 hours. The cold carcasses were divided lengthwise into two equal parts and the right side were used to evaluate the weight of the carcass parts, including the neck, brisket, shoulder, legs, loin, and fat-tail according to recommendation of Dayani *et al.* (2011). Then, each part was dissected to lean meat and bone and weighed.

Statistical analyses

Data of growth performance, offal, carcass analysis, and blood metabolites (n=10 per treatment) were analyzed according to completely randomized design using the General Linear Model procedure of SAS (2005). The initial BW of the lambs and the carcass weight were used as a co-variate for the final BW and carcass components, respectively. The statistical model was:

$$Y_{ijk}= \mu + T_i + \beta X_k + e_{ijk}$$

Where:
Y_{ijk}: measured trait.
μ: general mean.
T_i: effect of treatment.
β: regression coefficient of trait.
X_k: initial weight.
e_{ij}: residual.

Means were separated using Duncan's multiple range test and were considered to be significant different at $P < 0.05$ level.

RESULTS AND DISCUSSION

The results of DMI, DWG, FCR, final BW, carcass weight, and dressing percentage of lambs fed experimental diets in different weeks of feeding are presented in Table 2. The lambs that received HPHS diet had significantly higher DMI than lambs fed LPHS diet in all feeding periods (P<0.05). Also, DWG was significantly highest in the lambs fed HPHS and lowest in the CON group (P<0.05). Also, FCR was significantly improved by HS feeding in all feeding periods. There was no significant difference in the initial BW of lambs fed the treatment diets. However, the final BW and warm carcass weight of lambs fed the HPHS diet were significantly higher than those of the other groups (P<0.05). The dressing percentage was not affected by the experimental diets.

As shown in Table 3, significant increase for cold carcass and brisket as well as carcass and brisket lean meat were observed for HPHS diet (P<0.05), while decreasing the CP level to 12% (LPHS) did not affect these traits (P<0.05). The bone weight and lean meat percentage were not affected by the experimental diets. The fat-tail also increased significantly by adding HS to lambs' diet (P<0.01). By supplementing HS and reducing the CP level in the diet of lambs (LPHS), the weight of neck, leg, and loin did not change significantly, but weight of the shoulder and the lean meat of the shoulder increased significantly by adding HS to the diet (P<0.05).

The experimental treatments had no effect on the weight of offal parts, such as the head, feet, pelt, heart, liver, kidneys, lung, spleen, and testicles (Table 4), while the visceral fat significantly increased by adding HS to lambs' diets (P=0.01).

As shown in Table 5, the addition of HS to the diets of lambs (HPHS and LPHS diets) significantly increased withers height (P<0.05). Also, the chest circumference increased by supplementing HPHS diet to lambs' diet, while reducing CP level (LPHS diet) had no effect compared with the CON diet (P<0.05). The tail circumference and tail length increased significantly with the addition of HS to the diet, with the highest values observed in the HPHS diet and the lowest in the CON diet (P<0.01).

Table 6 presents the blood metabolites of lambs fed with experimental diets. Significantly, the highest concentration of glucose, total protein, and albumin was observed in lambs fed HPHS and LPHS diets (P<0.05). The concentration of HDL and cholesterol in the blood of lambs significantly increased with the addition of HS to the diet (P<0.05), while these two parameters were significantly lower in LPHS diet than HPHS diet. Blood triglyceride concentration in lambs fed with HPHS diet was significantly higher than other groups (P<0.01).

Similar to the results of the present experiment, the chemical composition of HS in terms of CP, EE, and ash have been reported as 26, 29 and 5.7%, respectively (Semwogerere *et al.* 2020). However, the amount of NDF in this report was inconsistent with the present results (14.9 *vs.* 32.8%). It has been reported that the chemical composition of HS is largely influenced by the variety and cultivation conditions (House *et al.* 2010). In this study, growth performance was affected by feeding HS, so that lambs received HPHS diet had significantly higher DMI, DWG, final live BW, and carcass weight than other groups. Although several factors affect feed intake, protein is one of the most important nutrients that affect DMI (Forbes, 2007). Therefore, lambs fed a high-protein diet often consume more DM. Previous studies showed that DMI was not consistently increased by sheep and beef cattle when full-fat oilseed (cottonseed and HS) was added to the diet (Gibb *et al.* 2005; Dayani *et al.* 2011).

Also, Roy *et al.* (2013) reported that feeding diets containing sunflower oil or soybean oil at 45 g/kg DM to goats did not affect DMI, which could be attributed to the similar metabolizable energy of the diets. Inconsistent DMI response to dietary fat supplementation reflects the complexity of both intake regulation and metabolism of fatty acid in the rumen.

Table 1 Ingredients and chemical composition of experimental diets and full-fat Hemp seed (HS)

Ingredient (g/kg of DM)	Experimental diets[1]			Hemp seed
	CON	HPHS	LPHS	
Alfalfa hay, chopped	250	250	250	-
Wheat straw, chopped	150	150	150	-
Barley grain, ground	300	230	235	-
Corn grain, ground	65.0	70.0	130	-
Hemp seed, full-fat	0.00	100	100	-
Wheat barn	115	115	115	-
Soybean meal	100	65.0	0.00	-
Minerals and vitamins supplement[2]	14.5	14.5	14.5	-
Limestone	1.50	1.50	1.50	-
NaCl	4.00	4.00	4.00	-
Chemical composition				
Metabolizable energy (Mcal/kg)	2.52	2.61	2.60	4.50
Crude protein (g/kg)	141	140	122	225
Ether extract (g/kg)	27.1	58.2	59.8	330
Neutral detergent fiber (g/kg)	367	365	362	149
Ash (g/kg)	75.0	75.4	75.0	45.6
NFC[3] (g/kg)	391	361	386	249

[1] CON: 14% CP without HS diet; HPHS: 14% CP + 10% HS diet and LPHS: 12% CP + 10% HS diet.
[2] Containing: vitamin D: 50000 IU/kg; vitamin A: 250000 IU/kg; vitamin E: 1500 IU/kg; Calcium: 120 g/kg; Manganese: 2.25 g/kg; Zinc: 7.7 g/kg; Magnesium: 20.5 g/kg; Iodine: 56 mg/kg; Sodium: 186 g/kg; Phosphorus: 20 g/kg; Iron: 1.25 g/kg; Copper: 1.25 g/kg; Sulfur: 3 g/kg; Cobalt: 14 mg/kg and Selenium: 10 mg/kg.
[3] Non fibrous carbohydrates= 1000 − (NDF+CP+EE+Ash).

Table 2 Dry matter intake, daily weight gain, feed conversion ratio, final body weight, carcass weight and dressing percentage of lambs fed experimental diets

Item	Experimental diets			SEM	P-value
	CON	HPHS	LPHS		
Dry matter intake (g/d)					
0-28 d	1195[ab]	1310[a]	1095[b]	53.9	0.04
28-56 d	1320[ab]	1475[a]	1205[b]	21.9	0.02
56-84 d	1381[b]	1490[a]	1240[b]	82.4	0.03
0-84 d	1298[b]	1425[a]	1180[c]	32. 5	0.03
Daily weight gain (g/d)					
0-28 d	191.5[c]	249.1[a]	211.5[b]	11.6	0.01
28-56 d	186.3[c]	242.5[a]	210.9[b]	19.4	0.02
56-84 d	205.1[b]	245.9[a]	212.8[ab]	42.6	0.09
0-84 d	194.3[b]	245.8[a]	211.7[b]	17.1	0.04
Feed conversion ratio (g DMI/g DWG)					
0-28 d	6.26[a]	5.16[b]	5.18[b]	0.35	0.02
28-56 d	7.08[a]	6.08[b]	5.71[b]	0.41	0.03
56-84 d	6.73[a]	6.19[b]	5.82[b]	0.54	0.02
0-84 d	6.68[a]	5.80[b]	5.57[b]	0.28	0.03
Initial body weight (kg)	25.7	25.8	25.9	1.89	0.78
Final body weight (kg)	42.0[b]	46.4[a]	43.6[b]	1.95	0.03
Warm carcass weight (kg)	20.8[b]	23.9[a]	21.2[b]	1.27	0.04
Warm dressing percentage (%)	49.4	51.9	50.9	1.01	0.30

CON: 14% CP without HS diet; HPHS: 14% CP + 10% HS diet and LPHS: 12% CP + 10% HS diet.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

The NRC (2007) suggested that lipids, especially sources with significant amounts of unsaturated fatty acids, alter the rumen acetate-propionate ratio and reduce DMI, but this happens when the total fat content in the diet is more than 6-7% (based on DM). The analysis of the chemical composition of the experimental diets (Table 1) showed that by adding HS to HPHS and LPHS diets, the fat content increased from 27.1 in the control diet to 58.2 and 59.8 g/kg, respectively.

The higher final BW and DWG of lambs fed HPHS diet in current study could be due to higher DMI and higher energy consumption. On the other hand, young lambs need sufficient protein, so supplementing the diet with high-quality protein and low ruminal degradability can improve growth performance (Webster and Povey, 1990). In the present research, in the LPHS diet compared to the CON diet, reduction in CP level from 14% to 12% did not effect on DWG, final BW, and warm carcass weight, but improved FCR. Contrary to our results, feeding HS to feedlot cattle had no effect on final live BW, DWG, carcass weight, or dressing percentage (Gibb *et al.* 2005). Also, researchers reported that supplementing 20% whole cottonseed (WCS) to lambs diet decreased DWG and final BW (Dayani *et al.* 2011). They reported four reasons: physical covering of fiber by lipids, lack of cations due to insoluble soaps formation, inhibition of microbial activity in the rumen, and modification of microbial population. The reason for this discrepancy in results can be attributed to the type of oilseed because it has been reported that HS oil and protein is protected by the seed hull and spared from rumen fermentation (Callaway, 2004).

In the present experiment, the improvement in FCR in lambs fed the HS-containing diet (HPHS and LPHS diets) can be attributed to the higher DWG. In sheep, fat supplementation increases plasma lipids, which can be used to maximize growth in post-weaning lambs (Febal *et al.* 2000). On the other hand, HS contains unsaturated fatty acids, terpenes, polyphenols, and lignans that are toxic to methanogens and its use in animal feed leads to the inhibition of methanogens in the rumen (Patra and Saxena, 2009; Teng *et al.* 2024). The decrease in the methane production may increase feed utilization efficiency as its emissions represent about 10% of gross energy loss from feed intake (Beauchemin *et al.* 2009). Thus, feed energy is directed to animal growth and animal performance is improved (Salami *et al.* 2019). It's reported that, feeding 20% WCS to lambs decreased DWG and final BW and did not affect DMI, resulting in negative impact on FCR (Dayani *et al.* 2011). The weight of warm carcass was higher for lambs fed HPHS diet than other groups. This can be attributed to higher final BW of these lambs. Values for dressing percentage lower than those obtained in the present study have been reported by others (Dayani *et al.* 2011) because dressing percentage is influenced by genotype (Papadimitriou *et al.* 1989).

The weights of cold carcasses, lean meat and fat-tail were greater for the animals fed HPHS diet than CON diet which can be due to greater final BW of lambs in this group. Contrary to our results, it has been reported that feeding HS (14% as feed) had no significant effect on carcass and meat quality traits in feedlot steers (Gibb *et al.* 2005) and lambs (Turner *et al.* 2012). Similar to the present results, Dayani *et al.* (2011) reported that when using WCS in diet of fattening lambs, dietary CP level could be decreased up to 2%.

The weight of shoulder was significantly increased in HS treatment lambs, while it did not affect neck, leg, and loin weight. The significant increase in the weight of shoulder and brisket and their loin meat in lambs fed with HPHS diet could be due to the increase in the final weight of lambs in this group. Higher meat yield in lambs fed diets with HS corresponds to better FCR, which may indicate the economic effects of using whole oilseeds for the meat production industry. In the present study, the higher fat-tail weight in lambs fed with HPHS diet was predictable since it has been reported that tail weight has a positive correlation with BW in lambs (Ben Hamouda and Atti, 2011).

The practical importance of visceral fat measurement is that this measure of fatness is considered as the best available indicators of fat depots at this carcass weight of lambs (Kandylis *et al.* 1998). So it may be said that, adding hempseed to diets increased carcass weight due to higher visceral fat. Except for visceral fat, no significant difference was observed for the weight of internal organs between lambs in the present experiment (Table 4). However, the weight of visceral fat was higher for the lambs fed diets containing HS than CON. The higher fat content in diets containing HS compared to the CON diet could be the reason this difference because it has been reported that feeding supplemental fats often enhances carcass fat (Felton and Kerley, 2004). Consistent with this finding, Absalan *et al.* (2011) reported that lambs fed with higher percentage of WCS had higher visceral fat content than control group. However, the findings of some studies differ from results of this study, since they report no effect of diet on the proportion of carcass fat when the post-weaning diets are supplemented with linseed (Berthelot *et al.* 2010).

In cattle, sheep, and goats, the length and girth of the animals are measured to estimate the live weight (Oke and Ogbonnaya, 2011), which are valuable for judging the quantitative characteristics of meat and are also helpful in developing suitable selection criteria (Islam *et al.* 1991). In the present study, wither height and chest circumference were consistent with the results of breast weight and shoulder weight because their weight was also increased in lambs fed HPHS. Greater tail circumference and tail length in lambs fed HPHS diet can be due to higher tail weight in these lambs. As reported by Agamy *et al.* (2013), in male lambs, tail dimensions are directly related to tail weight. Although the Baluchi sheep is a tail breed, few experiments have been designed to measure the dimensions of the tail and its relationship with other carcass characteristics.

In confirmation of our results, it has been reported that feeding oils had no effect on concentrations of glucose in serum (Roy *et al.* 2013).

Table 3 Half cold carcass cuts of lambs fed experimental diets

Item (kg)	Experimental diets			SEM	P-value
	CON	HPHS	LPHS		
Carcass	9.54^{b}	10.9^{a}	10.2^{ab}	0.45	0.04
Lean meat	6.73^{b}	7.52^{a}	7.07^{ab}	0.30	0.02
Bone	1.56	1.54	1.49	0.05	0.19
Lean meat (%)	70.5	68.9	69.7	3.54	0.11
Fat-tail	1.25^{c}	1.86^{a}	1.59^{b}	0.08	0.01
Neck	0.78	0.84	0.75	0.09	0.06
Lean meat	0.56	0.58	0.49	0.07	0.19
Bone	0.21	0.26	0.26	0.04	0.09
Lean meat (%)	71.8	69.0	65.3	4.42	0.13
Shoulder	1.44^{b}	1.66^{a}	1.60^{a}	0.07	0.04
Lean meat	1.16^{b}	1.39^{a}	1.34^{a}	0.07	0.04
Bone	0.27	0.27	0.26	0.02	0.77
Lean meat (%)	80.6	83.7	83.6	1.94	0.07
Brisket	1.68^{b}	1.94^{a}	1.83^{ab}	0.13	0.01
Lean meat	1.39^{b}	1.66^{a}	1.57^{ab}	0.13	0.01
Bone	0.30	0.28	0.26	0.02	0.09
Lean meat (%)	82.7	85.6	85.8	2.48	0.14
Leg	2.74	2.85	2.73	0.15	0.60
Lean meat	2.43	2.52	2.41	0.13	0.94
Bone	0.32	0.33	0.32	0.05	0.20
Lean meat (%)	88.7	88.4	88.3	1.55	0.12
Loin	1.65	1.77	1.65	0.08	0.95
Lean meat	1.19^{b}	1.37^{a}	1.26^{ab}	0.06	0.02
Bone	0.47	0.40	0.39	0.05	0.15
Lean meat (%)	72.1^{b}	77.4^{a}	76.4^{ab}	1.88	0.02

CON: 14% CP without HS diet; HPHS: 14% CP + 10% HS diet and LPHS: 12% CP + 10% HS diet.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 4 Offal parts of lambs fed experimental diets

Item (kg)	Experimental diets			SEM	P-value
	CON	HPHS	LPHS		
Head	2.61	2.68	2.70	0.12	0.74
Feet	0.93	0.95	0.95	0.04	0.81
Pelt	4.15	4.50	4.14	0.27	0.51
Heart	0.15	0.15	0.16	0.01	0.08
Liver	0.65	0.72	0.63	0.04	0.06
Kidneys	0.12	0.12	0.12	0.01	0.96
Lung	0.43	0.44	0.39	0.03	0.40
Spleen	0.06	0.06	0.06	0.01	0.67
Visceral fat[1]	0.89^{b}	1.63^{a}	1.46^{a}	0.03	0.01
Testicles	0.27	0.35	0.32	0.03	0.07

[1] It includes kidney fat, heart fat, abdominal fat and intestinal fat.
CON: 14% CP without HS diet; HPHS: 14% CP + 10% HS diet and LPHS: 12% CP + 10% HS diet.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 5 Biometric parameters of lambs fed experimental diets

Item (cm)	Experimental diets			SEM	P-value
	CON	HPHS	LPHS		
Live body length	72.2	74.1	72.6	1.31	0.49
Withers height	59.3^{b}	62.1^{a}	64.9^{a}	1.55	0.02
Chest circumference	90.6^{b}	103^{a}	87.7^{b}	3.57	0.03
Warm carcass length	69.2	73.2	71.3	1.15	0.13
Cold carcass length	68.7	70.8	69.2	1.37	0.45
Tail circumference	63.6^{c}	69.7^{a}	66.6^{b}	0.43	0.01
Tail length	30.3^{c}	52.3^{a}	39.6^{b}	3.70	0.01

CON: 14% CP without HS diet; HPHS: 14% CP + 10% HS diet and LPHS: 12% CP + 10% HS diet.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 6 Serum metabolites of lambs fed experimental diets

Item	Experimental diets			SEM	P-value
	CON	HPHS	LPHS		
Glucose (mg/dL)	78.3[b]	89.5[a]	89.3[a]	3.02	0.04
Total protein (g/dL)	6.88[b]	7.93[a]	7.25[a]	0.27	0.03
Albumin (g/dL)	3.23[b]	3.86[a]	3.90[a]	0.19	0.05
Creatinine (mg/dL)	0.95	0.70	0.70	0.10	0.57
Urea N (mg/dL)	3.96	3.31	3.08	0.29	0.08
HDL (mg/dL)	29.0[c]	39.0[a]	35.0[b]	1.08	0.02
Triglyceride (mg/dL)	19.8[b]	27.5[a]	19.5[b]	2.94	0.01
Cholesterol (mg/dL)	55.0[c]	75.8[a]	63.3[b]	2.79	0.03

CON: 14% CP without HS diet; HPHS: 14% CP + 10% HS diet and LPHS: 12% CP + 10% HS diet.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Similarly, Abrahamsen *et al.* (2021) did not observe any significant difference in blood glucose concentration by adding different levels of HS meal to the diet of fattening goats. Albumin is synthesized in the liver and used to maintain homeostasis throughout the body. The reported normal levels of albumin in healthy sheep vary rather widely, ranging from 2.4 g/dL to over 4.0 g/dL (Sidki and Hirst, 1998). Albumin values obtained in the present experiment were in the same range. On the other hand, the total serum protein values obtained in HPHS and LPHS treatments were slightly higher than the biological range (6.4 to 7.0 g/dL) reported by Aiello (2016). Probably, more rumen undegradable protein in HS has provided more protein for absorption in the intestine and increased serum protein because HS protein is protected by the seed hull and spared from rumen fermentation (Callaway, 2004).

Abrahamsen *et al.* (2021) reported that total serum protein concentration of growing goats was quadratically affected by increasing the level of HS meal in the diet, and it was higher in the control and 30% HS meal treatments than in the 10 and 20% HS meal treatments. The conflicting results found in the current study could be attributed to the differences in protein sources. The observed changes for increasing HDL, TG, and cholesterol concentrations in the blood of lambs fed HS diets compared to control diet were expected because lipid supplementation generally increased these plasma lipid fractions (Bernard *et al.* 2009). In agreement with this finding, Dayani *et al.* (2011) reported that blood cholesterol and HDL increased with the WCS feeding. They considered the reason for this increase to be more EE in diets containing 20% WCS compared to the control diet (6% *vs.* 2.44%). On the other hand, Cozma *et al.* (2015) reported that dietary supplementation in goats with HS oil did not modify plasma cholesterol, TG, or phospholipid concentrations, while total lipid concentration in plasma was increased. According to these authors, this increment could be due to the higher fat intake with the supplemented diet.

CONCLUSION

Feeding full-fat hemp seeds at 10% of the diet for 84 d increased DMI, DWG, and carcass weight and improved FCR in fattening male lambs, while it had no effect on most of offal parts and gastrointestinal components. On the other hand, reducing the CP level in the diet containing HS did not affect the performance and carcass characteristics than CON diet. In general, HPHS diet caused a better performance and LPHS diet was more or less similar to the control group. The results of the present experiment showed that by replacing 10% of the diet of fattening lambs with full-fat hemp seeds, it is even possible to reduce the CP level of the diet by about 2%.

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