

Dietary sesame seed hulls utilization on lamb performance, lipid oxidation and fatty acids composition of the meat

E. Bonos^{1*}, A. Kargopoulos², Z. Basdagianni³, D. Mpantis², E. Taskopoulou², B. Tsilofiti² and I. Nikolakakis²

¹Research Institute of Animal Science / ELGO-Dimitra, Paralimni Giannitsa, 58100, Pella, Greece

²School of Agriculture Technology, Food Technology and Nutrition, Department of Agricultural Technology, Technological Educational Institution of Western Macedonia, 53100, Florina, Greece

³Faculty of Agriculture, Forestry and Natural Environment, School of Agriculture, Aristotle University of Thessaloniki, 54124, Thessaloniki, Greece

Abstract

The objective of this study was to evaluate the dietary use of sesame seed hulls on lamb performance parameters and some meat quality characteristics. A total of 36 lambs of Pelagonia (Florina) breed 68 ± 5 days old and with average initial body weight 18.5 ± 2.6 kg, were randomly allocated to 3 groups. The lambs of the Control group were fed a normal diet based on alfalfa hay, wheat straw and concentrate feed (mainly maize, barley and soybean meal), whereas those from Groups S100 and S200 were fed alfalfa hay, wheat straw and concentrate feeds containing sesame seed hulls at 100 g/kg feed and 200 g/kg feed, respectively. After 9 weeks, experimental period, the animals of Group S200 had significantly ($P < 0.05$) better final body weight, fasting live weight, weight with empty rumen, hot carcass weight, and cold carcass weight compared to the Control group. Moreover, the dressing percentage was significantly higher ($P < 0.05$) for group S200, compared to group S100, but not compared to the controls. Meat lipid oxidation measured as thiobarbituric acid reactive substances content did not differ among all three groups ($P > 0.05$) after 2 or 4 days of refrigeration. Moreover, the fatty acid profile of the meat did not differ ($P > 0.05$) for saturated, monounsaturated and polyunsaturated fatty acids among all groups. In conclusion, sesame seed hulls can be used in lamb nutrition with some possible benefits regarding the performance parameters.

Introduction

The feedstuffs market is suffering from price fluctuations and quite often availability problems [1-3]. These detrimental situations are usually observed for high protein feeds such soybean meal [4], but they can also be observed for cereals such as maize [5] and barley [6], and other feed ingredients. Consequently, farmers have problems with supplying their livestock with good quality feeds, while keeping the feed cost at manageable levels. Accordingly, nowadays there is an observed increased demand for novel feedstuffs characterized by low price and decent availability, which can be utilized in livestock feeds, without any adverse effects on animal health and productivity. Therefore, many by-products of the food and feed industries are now being examined as alternative feedstuffs.

Sesame (*Sesamum indicum*) can be considered as a significant oil producing plant, which is cultivated mainly for the production of sesame bread, tahini (or tehineh), halva and sesame oil [3,7,8]. According to FAO data for 2010 [9], sesame seed production occupied 78 million acres, with a production of 3.84 million tons. The sesame seeds contain on average 44 to 58% oil, 18 to 25% crude protein, 13.5% carbohydrates and 5% ash [10-13]. The sesame seeds oil fatty acid composition is on average 18.5% saturated fatty acids (SFA), 45.4% monounsaturated fatty acids (MUFA), and 36.1% polyunsaturated fatty acids (PUFA), with oleic and linoleic acids being the main components [13]. Also, sesame seeds contain high amounts of the natural antioxidants sesamin, sesamol, and sesaminol glucosides [3,13-15], which are considered beneficial for animal health. The sesame oil also contains high quantities of these antioxidant polyphenolic compounds, which makes it resistant to oxidation [12,13,15].

During the oil extraction of sesame seeds and the production of

tahini, the seeds are dehulled and the kernels are further processed. The produced sesame seed hulls (SSH) on average represent the 12.0% to 13.6% of the initial seed weight, and they also contain a significant percentage of small unbroken seeds that escape the hulling process [13]. The chemical composition of the SSH varies between different extraction facilities [3,13], due to the different oil extraction processes. The SSH are utilized in some countries in livestock nutrition, but published data examining the effect of dietary SSH on farm animals performance, and especially on animal product quality, for example meat lipid composition and resistance to oxidation, are very limited [3,16-18].

The aim of this study was to examine the possible effects of replacing parts of soybean meal and maize with SSH in the diet of Pelagonia (Florina) growing lambs, focusing on the performance parameters, carcass quality, meat oxidation during refrigerated storage, and meat fatty acid composition

Materials and methods

Sesame seed hulls procurement

The SSH examined in this experiment were provided by a white

Correspondence to: Dr. Eleftherios Bonos, Research Institute of Animal Science / ELGO-Dimitra, Paralimni Giannitsa, 58100, Pella, Greece; Tel: +30 6976191742; E-mail: eleftherios.bonos@gmail.com

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sesame seed processing factory in Greece, that produces halva and tehneh. The hulls were analysed according to the proximate analysis guidelines of AOAC [19] for dry matter, crude protein, crude fat, crude fiber, neutral detergent fiber (NDF), acid detergent fiber (ADF), ash, and total carbohydrates. The metabolizable energy content of the SSH was estimated based on NRC [20] and Obeidat and Gharaybeh [16]. The chemical composition and metabolisable energy of the SSH is presented in Table 1.

Animals and diets

The animal experiment was performed in the animal farm of the School of Agriculture Technology, Food Technology and Nutrition, of the Technological Educational Institution of Western Macedonia, Florina, Greece. The animal handling and experimental procedures were performed to the principles of the Greek Directorate General of Veterinary Services for the care of animals in experimentation.

A total of 36 lambs (18 male and 18 female) of Pelagonia (Florina) breed (*Ovis aries*) were used in the experiment. These lambs were initially 68 ± 5 days old (Mean \pm St.Dev.) with initial body weight of 18.5 ± 2.6 kg (Mean \pm St.Dev.), which did not differ significantly ($P > 0.05$) between males and females. All lambs were individually marked and then were randomly allocated to three treatment groups of 12 lambs each (6 male and 6 female). Each lamb was individually housed in a separate pen (2.7 m²) with hay litter, equipped with appropriate feeder and waterer.

During the 9 weeks of the trial the lambs from the Control group were given a normal rearing ration which was based on alfalfa hay, wheat straw and concentrate (mainly maize, barley and soybean meal). The lambs from Groups S100 and S200 were fed alfalfa hay, wheat straw and concentrate feeds containing SSH at 100 g/kg feed and 200 g/kg feed, respectively. The concentrate feeds of S100 and S200 groups were calculated to be isonitrogenous and isocaloric to the concentrate feed of the control group. The composition and chemical analysis [19,21] of the examined concentrate feeds is given in Table 2. For all groups, the alfalfa hay and the wheat straw were provided in raw form, whereas the concentrate feed was provided in powder form. Feed and drinking water were provided *ad libitum*.

Measurements

All lambs were individually weighed at the beginning and the end of the trial, and individual feed consumption was recorded daily. At the end of the experiment all lambs were slaughtered after 24 hours of fasting. Fasted live weight was recorded immediately before slaughter and hot carcass weight after slaughter. Empty live weight was calculated by subtracting rumen content weight from the fasted live weight. Cold carcass weight was recorded after keeping the carcass at 4°C for 24h.

Table 1. Chemical composition of sesame seed hulls.

	g/ kg of Feed	g / kg of Dry matter
Dry matter	970.0	-
Crude protein	108.3	111.6
Crude fat	134.2	138.4
Crude fiber	171.0	176.3
Ash	165.0	170.1
Neutral Detergent Fiber (NDF)	165.6	170.7
Acid Detergent Fiber (ADF)	123.2	127.0
Total carbohydrates	126.0	129.9
Ca	97.2	100.2
Metabolizable Energy (MJ/kg)	15.9	16.4

Table 2. Ingredients and chemical composition of experimental diets.

Ingredients, g/kg	Control	S100	S200
Maize	250	130	-
Barley	295	340	380
Wheat bran	70	70	70
Soybean meal	125	80	40
Wheat straw	-	20	50
Alfalfa hay	220	220	220
Sesame seed hulls	-	100	200
Monocalcium phosphate	10	10	10
Calcium carbonate	5	5	5
Salt	10	10	10
Vitamin and mineral premix ¹	15	15	15
Total	1000	1000	1000
Chemical composition, g/kg of feed			
Dry matter	897	902	908
Crude protein	191	188	187
Crude fiber	110	136	165
Crude fat	30	44	58
ADF	144	169	199
NDF	261	295	336
Ash	58	86	117
Metabolizable Energy (MJ/kg)	12.6	12.6	12.9

¹ Premix supplying per kg of feed: 5.85 g Ca; 1.22 g P; 9000 I.U. vitamin A; 3.75 mg vitamin B₁; 1300 I.U. vitamin D₃; 24.5 mg vitamin E; 0.5 mg Co; 2 mg Cu; 0.7 mg I; 30 mg Fe; 52 mg Mn; 0.24 mg Se; 80 mg Zn.

Dressing percentage was calculated as hot carcass weight/empty live weight. Carcass yield was calculated as cold carcass weight/empty live weight. Samples were taken from the rib steaks (*Longissimus dorsi* muscle) and the thighs (*Gluteii* muscles), from all the animals of each group, which were immediately vacuum packed and frozen (-45°C) for further analysis.

Lipid oxidation of the rib steak and thigh samples was determined according to a modified Vyncke's [22] method, as described by Kasapidou *et al.* [23]. The previously frozen samples were placed in refrigeration conditions (1°C) in a normal fridge, with each sample on a separate plate. One half of the total number of samples was kept refrigerated for 2 days and the other half for 4 days before performing the lipid oxidation analysis. Initially, the muscles of each sample were separated from the bones, and after external/adjacent fat and connective tissue was removed, they were ground in a food processor (Moulinex, France). Subsamples (5 g) were homogenized in 25 ml of 7.5% trichloroacetic acid (w/v) containing 0.1% (w/v) of both n-propyl gallate and ethylenediaminetetraacetic acid disodium salt, using a Polytron (Kinematica AG, Littau, Switzerland model PT-MR 3000). The obtained samples were left for approximately 15 to 20 min to allow the extraction of the thiobarbituric acid reactive substances (TBARS) and the resulting slurry was filtered, and 5 ml of the filtrate was mixed with 5 ml of 0.02 M thiobarbituric acid. A sample containing 5 ml of the trichloroacetic acid solution and 5 ml of the thiobarbituric acid solution was prepared to be used as blank. All samples were left in the dark overnight, and the next day absorbance was read at 532 nm against the blank sample using an UV-VIS spectrophotometer (U-2800 Double Beam Spectrophotometer, Hitachi, Tokyo, Japan). TBARS content was calculated using 1,1,3,3-tetraethoxypropane (5–20 nM) as standard and expressed as mg of malondialdehyde per kg of muscle. Each sample was analyzed twice and the average value was calculated.

Moreover, the fatty acid composition of the rib steak muscle samples was determined by gas chromatography. Fatty acids methyl esters were obtained from the frozen samples using the protocol described

by O'Fallon *et al.* [24]. Then, the separation and quantification of the fatty acid methyl esters was carried out with a gas chromatographic system (TraceGC model K07332, ThermoFinnigan, ThermoQuest, Milan, Italy) equipped with a flame ionization detector and a fused silica capillary column (30 m x 0.25 mm i.d., coated with cyanopropyl polysiloxane (phase type SP-2380) with a film thickness of 0.20 µm. Supelco, Bellefonte, PA, USA) and a model CSW 1.7 chromatography station (CSW, DataApex Ltd, Prague, Czech Republic) and. The chromatographic conditions were: Carrier: N₂, Flow: 1 ml/min; Oven: Temperature 70°C for 0.5 min, increase 30°C/min to 180°C for 10 min, increase 5°C/min to 225°C for 10 min; Inlet temperature: 250°C; Detector temperature: 250°C; Injection: 1 µl, with split 1/20. Fatty acid methyl esters retention times and elution order were identified using 'Tridecanoic acid' (T0502-5G, Sigma-Aldrich, USA) internal standard and reference standards: 'F.A.M.E Mix C8-C24' (C.N. 18918-1AMP, Supelco, USA), '37 Component FAME Mix' (47885-U, Supelco, USA), 'Linoleic acid methyl ester cis/trans isomers' (4-7791, Supelco, USA), as well as accompanying Supelco reference material for the column.

Statistical analysis

In all measurements, the experimental unit was each individual animal. Experimental data were analyzed with the aid of IBM SPSS Statistics 20 software (IBM, USA), using the general linear model function. For the performance parameters, Group and Sex were used as fixed factors in a two-way analysis of variance (ANOVA), and their possible interaction (Group x Sex) was also examined. For the lipid oxidation analysis Group and Tissue used were used as fixed factor in a two-way ANOVA, and their possible interaction (Group x Tissue) was examined. Moreover, for the fatty acid composition analysis the Group was used as a fixed factor in a one-way ANOVA. Values of $P < 0.05$ were considered significant. The homogeneity of the variances was examined with Levene's test and post-hoc analysis was undertaken with Tukey's test to identify the differences between the means.

Results and discussion

The SSH used in this trial contained a moderate amount of crude fat and crude protein. SSH chemical composition can vary greatly, depending on the processing method and collection stage. For example, Elleuch *et al.* [13] examined two different SSH products with very different chemical compositions (dry matter: 83.79% vs. 97.02%;

crude fat: 12.21% vs. 32.84%; crude protein 10.23% vs. 18.35%) which were collected before and after roasting the seeds. Also, Farran *et al.* [18], examined a SSH with moderate amount of crude protein (15.20%) and high amount of ether extract (25.81%). In addition, Obeidat and Gharaybeh [16], used a SSH with high amount of crude protein (25.8%) and moderate amount of ether extract (17.6%). Roasting of the seeds during processing removed moisture and increased the dry matter of SSH. Also, the relatively high crude fat content can be the result of a high number of small seeds that escaped the hulling process. This can be considered beneficial for the feed with such SSH addition, as it increases the energy and antioxidants content. Generally the oil content and protein of the oil seeds by-products is largely affected by the plant variety, as well as the extraction process, for example mechanical or solvent extraction, dehulling and roasting [13,25,26].

All lambs completed the study without any noticeable health problems. The effect of SSH dietary supplementation on the lamb performance parameters is reported in Table 3. The average daily weight gain was significantly ($P=0.027$) higher for group S200 compared to the controls. Also, the average daily feed consumption was significantly higher ($P < 0.001$) for group S100 compared to the other two groups, as well as significantly higher for group S200 compared to the controls. The feed conversion ratio (kg of feed / kg of weight gain) did not differ ($P=0.058$) among the groups. Moreover, the male lambs consumed higher quantities of feed compared to the females ($P < 0.001$), and had higher ($P=0.001$) average daily weight gain, with lower ($P=0.021$) feed conversion ratio. In an earlier experiment by Obeidat and Aloqaily [17] who examined the dietary use of SSH on Awassi lambs, it was reported that dry matter and organic matter intake was significantly greater for lambs feed diets with SSH compared to controls. Also, in another experiment [16] with black goat kids, it was found that dry matter, organic matter and crude protein intake diets with 10% SSH, was higher compared to controls or diets with 20% SSH. Differences in feed intake may be attributed to modified palatability, digestibility and/or lower dustiness, for example due to the increased crude fat in the diets supplemented with SSH [16,17].

Regarding the carcass parameters, it was noticed that the final body weight at the end of the trial was significantly ($P=0.005$) higher for the S200 group, compared to the controls. Moreover, significant improvements were found for the S200 group fasting live weight

Table 3. Effect of dietary sesame seed hulls on lamb performance parameters (Mean ± St. Dev).

	Average daily weight gain	Average daily feed consumption	Feed conversion ratio	Final body weight	Fasting live weight	Empty live weight ¹	Hot carcass weight	Cold carcass weight	Dressing percentage ²	Carcass yield ³
Groups	kg/day	kg	kg feed / kg gain	kg	kg	kg	kg	kg	%	Kg / 100 kg of Body weight
Control	0.19 ^b ± 0.06	0.99 ^c ± 0.02	5.81 ± 1.63	30.8 ^b ± 3.4	28.6 ^b ± 3.2	27.0 ^b ± 2.9	14.8 ^b ± 1.7	14.0 ^b ± 1.6	54.9 ^{ab} ± 0.6	49.0 ^b ± 0.4
S100	0.22 ^{ab} ± 0.06	1.03 ^a ± 0.02	4.93 ± 1.28	32.4 ^{ab} ± 3.2	30.6 ^{ab} ± 3.0	29.0 ^{ab} ± 2.8	15.6 ^{ab} ± 1.6	15.1 ^{ab} ± 1.5	54.4 ^b ± 1.3	49.3 ^a ± 0.4
S200	0.25 ^a ± 0.05	1.02 ^b ± 0.02	4.20 ± 0.70	34.2 ^a ± 2.5	32.0 ^a ± 3.2	29.8 ^a ± 2.3	16.6 ^a ± 1.3	15.7 ^a ± 1.3	55.6 ^a ± 0.7	49.2 ^{ab} ± 0.3
P	0.027	<0.001	0.058	0.005	0.006	0.011	0.004	0.004	0.011	0.048
Sex										
Male	0.25 ^a ± 0.06	1.03 ^a ± 0.02	4.34 ^a ± 1.19	34.4 ^a ± 2.7	32.2 ^a ± 2.7	30.2 ^a ± 2.5	16.7 ^a ± 1.4	15.9 ^a ± 1.4	55.3 ^a ± 1.0	49.4 ^a ± 0.3
Female	0.19 ^b ± 0.05	0.99 ^b ± 0.02	5.62 ^b ± 2.02	30.4 ^b ± 2.6	28.6 ^b ± 2.6	27.0 ^b ± 2.3	14.8 ^b ± 1.3	14.0 ^b ± 1.3	54.6 ^b ± 0.9	48.9 ^b ± 0.2
P	0.001	<0.001	0.021	<0.001	<0.001	<0.001	<0.001	<0.001	0.026	<0.001
Interaction P:										
Group x Sex	0.711	0.099	0.586	0.732	0.755	0.567	0.708	0.735	0.755	0.669

Groups: Control = 0 g SSH / kg; S100 = 100 g SSH / kg; S200 = 200 g SSH / kg.

¹ Empty live weight was calculated by subtracting rumen content weight from the fasted live weight

² Dressing percentage was calculated as hot carcass weight / empty live weight.

³ Carcass yield was calculated as cold carcass weight / empty live weight

^{a,b,c} Values in the same column with no common superscript differ significantly ($P < 0.05$)

($P=0.006$), empty live weight ($P=0.011$), hot carcass weight ($P=0.004$) and cold carcass weight ($P=0.004$) compared to the control group. The dressing percentage was significantly higher ($P=0.011$) for the S200 group, compared to the S100 group, but not compared to the control group. Also, the S100 group had a significantly ($P=0.048$) higher carcass yield compared to the control group, whereas the S200 group was not different. Additionally, the male lambs had significantly better final body weight ($P<0.001$), fasting live weight ($P<0.001$), empty live weight ($P<0.001$), hot carcass weight ($P<0.001$), cold carcass weight ($P<0.001$), dressing percentage ($P=0.026$) and carcass yield ($P<0.001$), compared to the females. No significant interaction was found between dietary groups and lamb sex. The lamb performance parameters and the differences between males and females are comparable to those previously reported for the Florina (Pelagonia) breed [27]. In a previous study of Obeidat and Aloqaily, [17] who examined the dietary use of 10% or 20% SSH on Awassi lambs ration, it was reported that final fasting live weight, hot and cold carcass weight and dressing percentage did not differ between these SSH groups and controls. Also, in a trial with black goat kids [16] fasting live weight, empty live weight, hot and cold carcass weight and dressing percentage did not differ between groups that consumed 10% or 20% SSH and controls. The improvement of the performance parameters in this trial can probably be attributed to the increased feed intake and/or improved utilization of the feeds.

A relationship between lipid peroxidation, meat acceptability and rancidity has been reported in beef [28]. Large increase of TBARS content can be tasted as an "oxidized" flavor in the meat, making it unacceptable for the consumers. Additionally, the consumption of oxidized fats can be considered as a risk factor for the consumer health, because some of the compounds formed during lipid peroxidation are related to mutagenic and carcinogenic effects, possibly having cytotoxic and genotoxic properties [29-32]. In this experiment, the effect of dietary SSH on thigh and rib steak meat lipid oxidation (TBARS content) after 2 and 4 days of refrigeration is presented in Table 4. No significant differences ($P>0.050$) were found between the three experimental groups for these measurements. Moreover, thigh and rib steak meat had similar TBARS content ($P>0.050$) after 2 days of refrigeration, but after 4 days the rib steak meat had significantly ($P=0.003$) higher quantities compared to the thigh meat. The lack of differences between the different consumed feeds can possibly be attributed to the sufficient levels of endogenous antioxidants in the feed ingredients, as well as the supplemented vitamin and mineral premix. The differences between thigh and rib steak on day 4 of refrigeration, but not on day 2 could be an index of different levels of antioxidant accumulation on the respective muscle tissue. Possible explanations for this effect could be the different levels of lipid deposition, as well as

Table 4. Effect of dietary sesame seed hulls on lamb thigh and rib steak meat lipid oxidation (TBARS*, mg malonaldehyde /kg muscle) after 2 and 4 days of refrigeration (Mean \pm St. Dev).

Group	After 2 days of refrigeration	After 4 days of refrigeration
Control	0.494 \pm 0.156	0.762 \pm 0.304
S100	0.522 \pm 0.101	0.729 \pm 0.213
S200	0.544 \pm 0.140	0.895 \pm 0.358
P	0.724	0.313
Tissue		
Thigh meat	0.482 \pm 0.734	0.629 ^a \pm 0.164
Rib steak meat	0.559 \pm 0.165	0.967 ^b \pm 0.298
P	0.171	0.003
Interaction P:		
Group x Tissue	0.700	0.955

Groups: Control = 0 g SSH / kg; S100 = 100 g SSH / kg; S200 = 200 g SSH / kg
^{a,b} Values in the same column with no common superscript differ significantly ($P<0.05$)

the percentage of unsaturated fatty acid content of the examined parts, which make the stored meat more prone to lipid peroxidation [3,33]. Another possible explanation is the difference of muscle types, i.e. the number of white vs red muscle fibers in the examined muscles, which affect the myoglobin content of the meat [33].

The fatty acid profile of the meat is important for the physicochemical and the sensorial parameters of the meat. Moreover, in recent years there is increased research interest in the possible modification of this profile, aiming to increase the content of fatty acids considered beneficial for the consumer health. Research has shown that ruminant meat fatty acid profile can be influenced by different rations [34], such as the inclusion of rich PUFA sources in cattle diets [35]. Dietary lipids are subjected to lipolysis by rumen bacteria, which then hydrogenate and isomerize the PUFA included in the feed to more saturated end products [36,37]. At the same time metabolites such as ruminic acid (9 *cis*, 11 *trans*-18:2) or vaccenic acid (11 *trans*-18:1) are produced, which are considered to be beneficial for the consumer [38]. Moreover, it is possible that rumen bacterial populations can be modified by dietary ingredients [36]. Therefore, since SSH contain a significant amount of sesame oil rich in PUFA, it was hypothesized that SSH inclusion in the sheep diets could modify the rumen function and sheep meat composition. Also, SSH have increased crude fiber content compared to soybean meal and maize, which may elevate rumen pH and further modify fatty acid production [38,39]. As it can be seen in Table 5, in this trial only limited differences were found for individual fatty acids, i.e. eicosenoic (20:1n-9) was higher ($P=0.002$) for S100 and S200 groups,

Table 5. Effect of dietary sesame seed hulls on lamb on the fatty acid composition (% of total fatty acids) of the rib muscle tissue (Mean \pm St. Dev.)

Fatty Acid	Common name	Control Group		S100 Group		S200 Group		P
		%	\pm	%	\pm	%	\pm	
12:0	Lauric	0.210	0.056	0.248	0.019	0.203	0.073	0.480
14:0	Myristic	2.695	0.797	3.301	0.137	2.646	0.737	0.311
14:1	Myristoleic	0.148	0.048	0.210	0.084	0.098	0.043	0.083
16:0	Palmitic	21.429	2.358	21.505	0.758	20.323	0.947	0.501
16:1	Palmitoleic	1.622	0.373	1.825	0.434	1.386	0.570	0.444
17:0	Heptadecanoic	0.908	0.113	0.978	0.174	0.742	0.095	0.080
17:1	Heptadecenoic	0.657	0.116	0.806	0.233	0.536	0.125	0.126
18:0	Stearic	14.162	1.930	14.073	2.304	13.099	1.854	0.724
9 <i>cis</i> -18:1	<i>cis</i> -Oleic	35.429	5.843	38.171	1.685	33.852	4.607	0.410
6 <i>trans</i> -18:2	<i>trans</i> -Linoleic	0.236	0.089	0.358	0.175	0.350	0.121	0.391
6 <i>cis</i> -18:2	<i>cis</i> -Linoleic	7.771	3.321	6.643	1.618	11.190	3.365	0.121
18:3n-6	γ -Linolenic	0.073	0.033	0.080	0.030	0.099	0.024	0.455
20:0	Arachidic	0.081	0.019	0.132	0.048	0.101	0.019	0.128
18:3n-3	α -Linolenic	1.155	0.214	1.025	0.041	0.935	0.190	0.228
20:1n-9	Eicosenoic	0.280 ^b	0.111	0.564 ^a	0.079	0.656 ^a	0.116	0.002
20:2	Eicosadienoic	0.062	0.030	0.053	0.006	0.079	0.029	0.344
20:3n-3	Eicosatrienoic	0.240	0.137	0.163	0.057	0.259	0.088	0.387
20:4n-6	Arachidonic	3.142	1.748	2.067	0.755	3.442	1.230	0.340
20:5n-3 EPA	Eicosapentenoic	0.463	0.283	0.268	0.098	0.354	0.087	0.351
24:0	Lignoceric	0.237	0.115	0.152	0.037	0.237	0.100	0.351
22:5n-3 DPA	Docosapentaenoic	1.112	0.580	0.682	0.168	0.856	0.166	0.288
22:6n-3 DHA	Docosahexaenoic	0.326	0.181	0.194	0.058	0.330	0.032	0.202
SFA	Total Saturated FA	40.502	3.608	41.166	1.805	38.151	1.708	0.260
MUFA	Total Monounsaturated FA	38.197	6.109	41.600	1.807	36.573	5.188	0.353
PUFA	Total Polyunsaturated FA	14.580	6.436	11.531	2.583	17.894	4.610	0.228

Groups: Control = 0 g SSH / kg; S100 = 100 g SSH / kg; S200 = 200 g SSH / kg
^{a,b} Values in the same row with no common superscript differ significantly ($P<0.05$)

compared to the controls. Accordingly, the most common fatty acids, as well as SFA, MUFA, and PUFA did not differ significantly ($P>0.050$) between the three experiments groups, in contrast with the original hypothesis of the experiment. It is possible that since SSH unsaturated fatty acids are not protected, they are quickly saturated in the rumen, before being absorbed along the small intestine of the animal [36,37,40].

Conclusion

The dietary incorporation of SSH in the diets of Pelagonia (Florina) growing lambs, improved the final body weight, fasting live weight, weight with empty rumen, hot carcass weight, and cold carcass weight, and feed intake, compared to controls. Meat oxidation did not differ during refrigerated storage conditions. Also, rib meat fatty acid composition did not differ for SFA, MUFA and PUFA, among the dietary treatments. Therefore, SSH could be used in lamb diets with possible beneficial effects on the performance. Additional research should be performed with different diet formulations to enable determination of the optimum supplementation levels in ruminant diets for increased performance and meat quality.

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