TÜBİTAK

Turkish Journal of Veterinary and Animal Sciences

http://journals.tubitak.gov.tr/veterinary/

Research Article

Turk J Vet Anim Sci
(2018) 42: 533-542
© TÜBİTAK
doi:10.3906/vet-1702-52

Effects of stoned olive pomace on carcass characteristics and meat quality of lambs

Ekin SUCU[1,*], Kadir Cem AKBAY[1], Ömer ŞENGÜL[1], Merve Tuba YAVUZ[2], İbrahim AK[1]

[1]Department of Animal Science, Faculty of Agriculture, Uludağ University, Bursa, Turkey

[2]Feyzsüt, Livestock Agriculture Food Industry and Trade Joint Stock Company, Bursa, Turkey

Received: 21.02.2017 • **Accepted/Published Online:** 28.11.2017 • **Final Version:** 10.12.2018

Abstract: Thirty-six Merino–Kıvırcık crossbred male lambs were utilized to evaluate the influence of two levels of dried stoned olive pomace. Lambs were blocked by initial body weights (BW, 20.4 kg) and randomly distributed into three groups. While one group received commercial concentrates without olive pomace, the second and third groups received an experimental diet containing 10% olive pomace and 20% olive pomace, respectively. They were fed for 49 days. The animals' BW and feed consumption were recorded weekly and biweekly, respectively. The lambs were slaughtered at the end of the trial. The carcass cut weights were recorded and a sample of LD muscle was collected for fat content and composition. Overall, there were no differences in slaughter characteristics, carcass measurements, or cut weights among the treatments ($P > 0.05$). The fatty acids (FAs) profile of LD muscle showed that 20% olive pomace fed animals had lower pentadecanoic and erucic acids, while they had higher oleic acid content ($P < 0.05$). This represents a favorable change in regard to human dietary guidelines. Total saturated, monounsaturated, and polyunsaturated FAs were not affected by treatments. There were minor differences in organoleptic properties among the treatments ($P > 0.05$). Meat rich in oleic acid fared best with panelists, which was found in the 20% olive pomace fed lambs.

Key words: Carcass traits, lamb, meat quality, dried stoned olive pomace

1. Introduction

In recent years climate change has contributed to decreased traditional grazing land and increased interest in sustainable feeding products to curb negative environmental effects. Grazing land in the Mediterranean climates is becoming rarer and lower in quality, especially in dry seasons (1). The production of animal foods as cost effective as possible is the basic need. Therefore alternative cheap feed sources are needed to promote sustainability, to ensure food security, and to protect the environment. Moreover, as the major livestock of this region, sheep offer unique abilities to utilize large amounts of noncompetitive and sustainable feedstuffs.

Olive oil is the main product of all Mediterranean economies. With the high levels of olive oil production and the new EU regulations a byproduct of olive oil production called olive pomace is now widely accessible (2,3). The new 3-phase extraction technology has led to highly digestible and more nutritious pomace being obtained. This process includes the removal of all seeds (stoning), which causes low amounts of cellulosic compounds and high amounts of residual fat (10%–15%), beneficial fatty acids, antioxidants, and valuable bioactive molecules (2,4,5). Indications suggest, however, that the nutritional value of olive pomace differs among regions, varieties, and the year of harvest (2).

Currently there is a desire among the public for high quality and lower fat lamb meat and olive pomace could provide the answer. The high oleic acid content in olive pomace may enhance the nutritional value of lamb for human consumption (6,7). Recent studies have shown the inclusion of stoned olive pomace to lambs diet modified the intramuscular fatty acids and increased the oxidative stability of lipids in lamb meat and altered subcutaneous fat composition (5,8,9). However, there is a lack of published data in the scientific literature regarding the effects of stoned olive pomace on carcass traits, meat quality, and organoleptic properties of the meat (10–12).

Our objective was to show the relationship between carcass traits, meat quality, and dietetic nutritional character with the inclusion of dried stoned olive pomace.

2. Materials and methods

2.1. Animal care and use

The experimental protocols used in this study were approved by the Institutional Animal Care and Use Committee (UÜHADYEK) (approval date: 04.03.2014;

* Correspondence: ekins@uludag.edu.tr

no: 2014-05/03). No health problems were detected in the experiment and the lambs remained free of disorders during the overall experimental period.

2.2. Animals, diets, and housing

Thirty-six lambs (Merino × Kıvırcık) were selected immediately after weaning (60 ± 5 days old and 20.4 ± 0.1 kg) from U.U. Center of Agricultural for Teaching and Research (40°11′N, 29°04′E). The lambs were reared in a naturally ventilated concrete block-finishing barn. Each pen contained a two-hole feeder and a single nipple waterer allowing ad libitum access to the feed and water. Temperature and relative humidity inside the barn were measured using a data logger (ebro, EBI 20, ebro Electronic GmbH & Co. KG, Ingolstadt, Germany) every hour on a daily basis over the duration of the experiment. During the experimental period (49 days), mean weekly ambient temperatures in the barn ranged from 19 to 23 °C and the mean weekly relative humidity ranged from 56% to 69%. The lambs were randomly split into 3 pens (12/pen) based on their body weights and randomly assigned to one of 3 treatments. After a three-phase oil extraction process, olive pomace was obtained from a local olive oil extraction mill (39°35′N, 27°1′E). The pomace was dried over about 50 min using a triple pass rotary drier (outlet air temperature was 80 °C and the product temperature was 60 °C). Afterwards stones were removed using a rotary gravity separator in a conjunction with air infiltration (TR 2013 04286 B patent). The diets were formulated to be isonitrogenous and isoenergentic and balanced to meet the nutritional requirements of the lambs (13). All the ingredients were mixed and pelleted (3 mm). The ingredients and chemical composition of the experimental diets are listed in Table 1. After a 7-day adaptation period three groups were formed to receive one of the following diets for 49 days. The first group was given the control diet (35.6% corn grain, 24% rice and wheat bran, 14% corn meal, and 4.3% mineral and vitamins). The second diet gradually increased soybean to 11.48% and decreased the corn meal 4%. The third increased the soybean to 15.8% and removed the corn meal. Both experimental diets eventually fully removed the soy bean oil. The lambs were weighed at the beginning of the experiment and every 2 weeks until the day before slaughter. Feeders in each pen also were weighed biweekly, and feed given and refused was recorded to determine average pen feed intake and feed efficiency (gain/feed intake). Feed offered and refused was sampled and dried for further chemical analysis (14,15).

2.3. Slaughter procedures and carcass evaluation

At the end of the feeding trial the lambs were weighed and transported to a private slaughterhouse following overnight removal of feed. The lambs were slaughtered under veterinarian supervision. Exsanguinations were performed by severing the carotid arteries and the jugular vein at the base of the neck. After skinning, the individual and aggregate weight of soft drops (heart, liver, and lungs with trachea, spleen, rumen, and intestine) and hard drops (head, skin, hide, forefeet, and hind feet) were recorded. The stomach and intestines were weighed before and after their contents were washed out. The soft and hard drops were expressed in relation to preslaughter body weight. After 48 h chilling at 4 °C, the carcasses were weighed again and a series of measurements were taken for each in accordance with the indications given by Colomer-Rocher et al. (16) for sheep carcasses. After the postmortem chill period, the cold carcass weight (CCW) and ultimate carcass pH were recorded. Cold carcass dressing (CCD) percentage was calculated using cold carcass weight (CCW) divided by final slaughter body weight (SBW) and then multiplying the result by 100. Carcass and leg length were measured to calculate compactness indices (cold carcass weight, kg/carcass length, m; leg weight kg/leg length, m). Carcass measurements were taken after cutting the carcasses in half through the center of the vertebral column. The left sides were weighed and then jointed into commercial cuts (neck, shoulder, brisket, rib, flank, loin, and leg). Commercial carcass cuts also were expressed as a percentage of chilled carcass weight. Afterwards, 12th rib fat thickness (RFT) and 12th rib longissimus muscle area (LMA) were measured on the right side of each carcass. The LMA was drawn on parchment and measured later with a digital planimeter and RFT measurements were taken 3/4 the length ventrally over the longissimus muscle by digital caliper (Placom KP-90N Roller, Japan) (17). Samples were taken and then packed, frozen, and stored at −20 °C to assess fatty acid composition, and used for sensory evaluation.

2.4. Fatty acids profile determination

Fatty acid profiles in experimental diets and muscle were determined by lipid extract (18). To determine the fatty acid composition of the fresh meat, samples of the transversal section were collected from the longissimus muscle and frozen for lipid extraction and methylation. Lipids were extracted using Folch's solution and the fatty acid methyl esters (FAME) were obtained by the ISO 5509 method (18). Qualitative and quantitative measurements of fatty acid content were performed by gas chromatography using a chromatograph (Agilent 6890N, China) with a flame ionization detector (FID) and capillary column (30 m × 0.25 mm i.d., 0.25 μm). Identification and quantification of the methyl esters of the fatty acids were achieved by comparison with the retention times and concentrations of methyl esters of standard fatty acids.

2.5. Panelist evaluation

A proportion of loin muscle of animals from each treatment was studied for sensory evaluation. Samples were thawed

overnight at 4 °C. Each sample was placed in absorbent paper for 30 s. External connective tissue and fat were trimmed and then cut into portions. Next, each group was wrapped separately in aluminum foil and cooked under an electric grill (Tefal, Turkey). The grill was switched on 15 min before cooking. The meats were grilled at 200 °C until the internal temperature reached 70 °C, monitored by an internal thermocouple. Afterwards, they were stored in a warm cabinet until served to the panelists. The total cooking loss was calculated from the differences between the weight of chop steaks before and after grilling. A total of 12 (6 female and 6 male) panelists volunteered to taste the lamb meat. The panelists received training prior to analysis according to the method described by Meilgaard et al. (19). They were provided samples by random, 3-digit codes and evaluated each one for taste on a 10-point scale (10 = excellent, 5 = fair, 1 = terrible) for scoring the following sensory properties of meat: tenderness, appearance, aroma, flavor, juiciness, and overall palatability. Crackers and water were served to the panelists between samples. Sensory tests were carried out in a sensory evaluation room, with white light and controlled ventilation, away from distracting noise and odors.

2.6. Statistical analyses

The data were analyzed by the GLM procedure of SAS (20) for completely randomized design. The individual parameters of the lambs were analyzed using a statistical model that included the effect of treatment doses (control, 10% olive pomace, and 20% olive pomace) (20). Panelist data were normalized within sex class to remove panelist differences in response to the rating scale (21). The data then were analyzed by the GLM procedure of SAS for completely randomized design with the main effects of treatment doses, sex, and their interaction (20). The results are reported as least squares means ± standard error means (SEM) and in all cases differences among means were declared as significant at $P < 0.05$, whereas trends were discussed at $P < 0.10$, unless stated otherwise.

3. Results

Inclusion of dried stoned olive pomaces did not result in any marked difference in proximate composition within lamb diets (Table 1). However, compared to the control diet (7.4%, 33.3%, and 9.20%, respectively), the olive pomace ingredients in the diets increased the fiber fractions such as crude fiber (9.7%), NDF (35.5%), and ADF (12.4%).

The olive pomace used in the diets had a high fat content (15.6%) and the pomace supplied 65% of total oleic acid consumed (Table 2). Including olive pomace in the diets supplied higher ($P < 0.05$) levels of oleic acid (18:1) and lowered ($P < 0.05$) levels of linoleic (18:2) and α-linolenic acids (18:3) compared to the control diet (Table 3).

Table 1. Ingredient formulation and chemical composition of the basal diet.

Ingredient, (%)	Control	OP10%	OP20%
Corn grain	35.58	35.82	35
Rice bran	14	13.2	7.66
Wheat bran	10.32	11.71	0
Soybean	9.5	11.48	15.81
Olive pomace	0	10	20
Corn grain meal	14	4	0
Sunflower meal	2	4	2.78
Barley	0	0	8.39
Corn gluten	7	3.3	4
Full soybean oil	0.79	0	0
Molasses	2.5	2.5	2.5
Marble powdered	3.1	2.7	2.6
Salt	0.52	0.6	0.57
Ammonium chloride	0.5	0.5	0.5
Commercial premix[1]	0.1	0.1	0.1
Biotin	0.05	0.05	0.05
Toxin binder	0.03	0.03	0.03
Vitamin E (pure)	0.01	0.01	0.01
Chemical composition, (% of DM*)			
Dry matter	87.96	88.6	89.09
Crude protein	16.04	16.00	16.00
Crude fiber	7.41	9.22	10.13
NDF[2]	33.33	35.67	35.35
ADF[3]	9.20	12.72	12.08
Ash	8.00	7.94	7.78
Crude fat	5.40	5.50	5.45
Calcium	1.32	1.20	1.20
Phosphorus	0.61	0.6	0.45
Metabolizable energy (kcal/kg DM)[4]	2757	2729	2734
Sodium, %	0.30	0.30	0.30
Starch	31.86	30.0	30.0

OP, olive pomace; 1: commercial premix (supplied per kg): vitamin A (50,000 IU), vitamin D3 (13,300 IU), vitamin E (13,300 IU), calcium (100 g), phosphorus (67 g), sodium (20 g), magnesium (19 g), iron (3 g), copper (0.1 g), manganese (8 mg), zinc (1 g), cobalt (0.1 g), iodine (0.2 g), selenium (0.005 g) .* Dry matter, 2: Neutral detergent fiber, 3: Acid detergent fiber, 4: Metabolizable energy estimation based on NRC (2001).

Table 2. Fatty acid composition of the dried stoned olive pomace.

Fatty acids	Olive pomace
Tridecanoic acid (C13:0)	<0.1
Myristic acid (C14:0)	<0.1
Pentadecanoic acid (C15:0)	<0.1
Palmitic acid (C16:0)	12.26 ± 0.01
Heptadecanoic acid (C17:0)	0.13 ± 0.01
Stearic acid (C18:0)	2.81 ± 0.01
Arachidic acid (C20:0)	0.49 ± 0.07
Behenic acid (C22:0)	0.31 ± 0.01
Tricosanoic acid (C23:0)	<0.1
Lignoceric acid (C24:0)	0.13 ± 0.01
SSFA	16.13
Myristoleic acid (C14:1)	<0.1
Cis-10 Pentadecenoic acid (C15:1)	<0.1
Palmitoleic acid (C16:1)	0.79 ± 0.01
Heptadecenoic acid (C17:1)	0.20 ± 0.01
Oleic acid (18:1 n9)	64.65 ± 0.01
Eicosapentaoic acid (C20:1 n9)	0.36 ± 0.01
Erucic acid (C22:1 n9)	0.18 ± 0.04
Nervonic acid (C24:1 n9) and (C22:6 n3)	0.58 ± 0.01
SMUFA	66.76
Linoleic acid (C18:2 n6)	15.28 ± 0.01
α-Linolenic acid (C18:3 n6)	0.87 ± 0.01
Arachidonic acid (C20:4 n6)	<0.1
Eicosapentaenoic acid (C20:5 n3)	<0.1
Docosadienoic acid (C22:2 n6)	2.11 ± 0.02
SPUFA	18.26

SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids

The treatment effects on slaughter, carcass characteristics, and carcass cuts are summarized in Tables 4 and 5. The initial body weight (20.4 kg; P = 1.0) and the slaughter weight (36.5 kg, P = 0.74), hot carcass (18.5 kg, P = 0.84), and chilled carcass weights (18.1 kg, P = 0.91) were similar among treatments, as well as the commercial dressing proportions (50%, P = 0.69). Data taken after chilling showed a greater shrinkage in olive pomace fed lambs (2.6% and 3.3% for OP10% and OP20%, respectively) compared to the control animals (1.8%), but it was not significant (P = 0.68). Presence of olive pomace had a highly significant effect on the weights of omental + mesenteric fat (186 g, P = 0.09) and perinephric + pelvic fat (377 g, P < 0.05) compared to the control animals (295 and 507 g, respectively). The perinephric + pelvic fat percentage in relation to the slaughter weight did not change (P = 0.98) but the omental + mesenteric fat percentage remained affected (P < 0.05). There were no differences observed among treatments for RFT (3.8 mm, P = 0.99) and LMA (14.4 cm^2, P = 0.85) as well as carcass ultimate pH (5.7, P = 0.75). The level of olive pomace in the diet had no effect (P > 0.05) on the carcass measurements, weights, and the proportions of the cuts (Table 5).

The fatty acid composition of the intramuscular fat is shown in Table 6. The total lipid content in muscle (4.13%) was not different (P = 0.93) among the diets (data not shown). In the total intramuscular lipids, there was no effect of the dietary treatment found on the percentage of the class of saturated fatty acids (SFA, 38% of total fatty acids) while monounsaturated fatty acids (MUFAs) were higher (P = 0.14; Table 6) in muscle from lambs fed with olive pomace. Thus, the ratio of SMUFA to SSFA increased (P = 0.17) when the olive pomace was included. In the LD muscle pentadecanoic acid (15:0) and erucic acid (22:1n9) were lower whereas oleic acid (18:1n9) was higher (P < 0.05) in lambs fed with olive pomace. Atherogenicity and thrombogenic indices were lower in meat from lambs fed with 20% olive pomace (0.67 and 0.99, respectively) compared to the control animals (0.73 and 1.04, respectively), but it was not significant (P = 0.46).

The sensory panel evaluation results are shown in Table 7. Cooking loss decreased (P < 0.001) in the order 10% olive pomace, 20% olive pomace, and control meat, with mean values of 36.6%, 40.2%, and 46.8%. The sex of panelists did not (P > 0.05) affect the ratings for taste. Although the meat from OP 20% lambs was rated with higher scores by the panelists, there seem to be minor differences in organoleptic properties for tenderness, appearance, aroma, flavor, juiciness, and overall palatability among the treatments (P > 0.05).

4. Discussion

Based on the chemical analysis of dried stoned olive pomace used in the lamb diets the following average values were obtained: dry matter 93.54%, crude protein 7.9%, crude fat 15.6%, crude fiber 31.0%, ash 6.3%, and ME 2847.2 mcal/kg DM (data not shown). The nutrient composition of dried stoned olive pomace as a sole ingredient is in line with the findings reported by Vera et al. (9). They also found high residual fat (16.5%), low NDF (32%), and low ADL (15.5%) content in stoned olive pomace from two-phase oil extraction (9). However, the protein content (5.6%) was lower and the oleic acid content of their olive pomace (75.3%) was higher than ours (7.9% and 65%, respectively). The pomace used in the current study was of considerably higher quality due to the stoning process and the drying procedure. Part of the difference was certainly

Table 3. Fatty acid composition of the lamb diets.

Diets	Control	OP10%	OP20%	SEM	P value
Myristic acid (14:0)	0.00b	0.08a	0.10a	0.00	<0.01
Palmitic acid (C16:0)	8.76b	8.53b	9.38a	0.09	<0.01
Stearic acid C18:0	1.81ab	1.58b	2.03a	0.09	<0.01
Arachidic acid (C20:0)	0.33b	0.33b	0.37a	0.00	<0.01
SSFA	10.90a	10.53a	11.88b	0.10	<0.01
Palmitoleic acid (C16:1)	1.00a	0.64b	0.58b	0.08	<0.01
Heptadecenoic acid (C17:1)	1.81ab	1.58b	2.03a	0.01	<0.01
Oleic acid (18:1 n9)	22.97c	29.62b	35.77a	0.16	<0.01
Eicosapentaenoic acid (C20:1 n9)	0.30b	0.55a	0.55a	0.01	<0.01
Docosadienoic acid (C22:2 n6)	18.58b	24.25a	24.02a	0.24	<0.01
SMUFA	24.27c	30.80b	36.90a	0.15	<0.01
Linoleic acid (C18:2 n6)	35.01b	28.29a	28.21a	0.13	<0.01
α-Linolenic acid (C18:3 n3)	2.04b	1.29a	1.35a	0.01	<0.01
Docosadienoic acid (C22:2 n6)	18.58b	24.25a	24.02a	0.14	<0.01
SPUFA	55.63b	53.93a	53.58a	0.27	<0.01

OP: olive pomace; SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids

Table 4. Effects of dried stoned olive pomace (OP) level on carcass and noncarcass characteristics in Merino × Kıvırcık lambs.

	Control	OP10%	OP20%	SEM	P value
Carcass parameters					
Initial weight (kg)	20.42	20.46	20.46	4.39	1.00
Slaughter weight (kg)	37.00	33.80	36.10	0.86	0.14
Hot carcass weight (HCW, kg)	18.40	16.60	18.60	0.36	0.11
Cold carcass weight (CCW, kg)	18.08	16.16	17.98	0.36	0.14
Chilling loss (%)[1]	1.75	2.60	3.31	1.23	0.68
Dressing (%)	49.73	49.26	51.53	0.98	0.46
Commercial dressing (%)[2]	48.87	47.89	49.82	0.74	0.69
RFT (mm)[3]	3.75	2.91	3.80	0.32	0.99
LMA (cm^2)[4]	14.8	14.44	14.66	0.83	0.85
LMA pH	5.71	5.67	5.69	0.01	0.75
Noncarcass components (as % of slaughter weight)					
Head	5.35	5.37	5.64	0.18	0.49
Skin + feet	11.05	10.92	11.73	0.44	0.41
Stomach and intestines	21.19	20.38	19.28	0.72	0.26
Offals[5]	4.84	4.69	4.91	0.14	0.58
Kidney	0.31	0.35	0.36	0.02	0.36
Testicles	0.37	0.40	0.40	0.04	0.70
Omental + mesenteric fat	1.36	1.05	0.90	0.21	0.04
Perinephric + pelvic fat	0.85	0.86	0.87	0.08	0.98

1: HCW – CCW/HCW × 100. 2: CCW/Slaughter weight × 100. 3: Rib fat thickness
4: Longissimus muscle area, 5: Liver-heart-spleen-lung

Table 5. Effects of dried stoned olive pomace (OP) level on carcass cuts and their percentage in Merino × Kıvırcık lambs.

	Control	OP10%	OP20%	SEM	P value
Cut weights, kg					
Right half carcass weight	9.04	8.29	8.99	0.19	0.67
Neck and thorax	1.33	1.28	1.39	0.06	0.62
Shoulder	1.79	1.76	1.78	0.04	0.90
Brisket	1.21	1.13	1.17	0.05	0.46
Rib	1.53	1.50	1.51	0.04	0.87
Flank	0.59	0.50	0.59	0.02	0.01
Loin	0.90	0.90	0.93	0.03	0.79
Leg weight	2.72	2.73	2.71	0.07	0.98
Carcass compactness (kg/m)	23.98	24.17	23.52	0.45	0.59
Leg compactness (kg/m)	5.32	5.31	5.34	0.13	0.98
Cut yields (%)					
Neck	14.71	14.52	15.43	0.69	0.70
Shoulder	19.78	19.95	19.75	0.30	0.88
Brisket	13.43	12.80	12.98	0.51	0.70
Rib	16.94	15.95	16.82	0.34	0.91
Flank	6.51	6.64	6.60	0.22	0.02
Loin	10.00	10.19	10.31	0.22	0.63
Leg	30.15	30.95	30.13	0.58	0.58
High priced joints[1]	59.93	61.09	60.19	0.80	0.60

1: Leg + shoulder + loin

related to the differing oil extraction methods (22). There were small differences in the proximate composition of the diets (Table 1).

The initial weight and the slaughter weight were not affected (P > 0.05) by olive pomace levels (Table 4). This is a consequence of similar nutritional characteristics of diets (2750 kcal/kg DM ME; 16.04% CP). These results are in line with recent findings showing that the initial live weight, final live weight, and feed intake of lambs were not affected by olive pomace supplementation (5,9,11). However, Awawdeh and Obeidat (23) reported that the inclusion of sun dried olive pomace in the lamb's diet as a substitute for 10% of wheat hay increased the growth rate and total body weight gain. On the other hand, Tufarelli et al. (24) found that lambs consuming oat hay replaced with 20% partially destoned exhausted olive pomace had lower final body weight (25.5 kg) and daily gain (178 g/day) compared to control animals (26 kg and 198 g/day, respectively). In another trial lower daily gain was also observed when lambs were given 30% olive pomace (25). Earlier studies have shown that in growing lambs adding more than 20% olive pomace is not recommended (26). However, the stoning process may contribute to better results (5).

Given there was no impact of dried stoned olive pomace on slaughter weight, a slight difference in carcass measurements was to be expected (Tables 4 and 5). The commercial dressing percentage was numerically higher (P = 0.69) on the olive pomace diets than those of the lambs on the control diet (48.9%); the highest dressing ratio (49.8%) was recorded for the highest olive pomace diet (20%). Greater net cold dressing percentages were also reported by Ragni et al. (11) by feeding 20% destoned olive pomace in Comisana lambs. Similarly, greater hot and chilled dressing percentage and right half carcass weight were obtained from 20% partially destoned exhausted olive pomace by Tufarelli et al. (24) and from 10% stoned olive pomace by Awawdeh and Obeidat (23). With the increased level of OP, the weight of internal body fat decreased in relation to carcass weight (Table 4). The presence of olive pomace, which contains a high percentage of oleic acid, seems to have considerably influenced the amount of internal fat deposition. Although the diets used in this experiment were isoenergetic and displayed similar

Table 6. Effects of dried stoned olive pomace (OP) level on fatty acid composition of Merino × Kıvırcık lamb meat.

Fatty acids of LD muscle	Control	OP10%	OP20%	SEM	P value
Capric acid (10:0)	0.12	0.08	0.10	0.01	0.68
Lauric acid (12:0)	0.15	0.11	0.14	0.02	0.41
Myristic acid (14:0)	1.97	1.93	1.84	0.22	0.77
Pentadecanoic acid (C15:0)	0.38a	0.32ab	0.29b	0.03	0.04
Palmitic acid (C16:0)	19.9	20.57	20.21	0.43	0.85
Heptadecanoic acid (C17:0)	1.11	1.12	1.01	0.07	0.58
Stearic acid (C18:0)	12.63	13.49	13.47	0.35	0.22
Arachidic acid (C20:0)	2.02	2.03	1.59	0.21	0.36
SSFA	38.28	39.65	38.65	0.57	0.86
Pentadecenoic acid (C15:1)	1.7	1.93	1.44	0.44	0.83
Palmitoleic acid (C16:1)	2.13	1.91	2	0.11	0.43
Heptadecenoic acid (C17:1)	0.76	0.71	0.64	0.06	0.32
Oleic acid (18:1 n9)	34.31b	33.59b	35.29a	0.73	0.01
Eicosapentaenoic acid (C20:1 n9)	2.78	4.90	4.26	1.15	0.63
Erucic acid (C22:1 n9)	0.67a	0.50b	0.18c	0.08	0.02
SMUFA	42.25	43.54	43.81	1.47	0.14
Linoleic acid (C18:2 n6)	9.87	8.61	8.57	0.59	0.89
α-Linolenic acid (C18:3 n3)	0.22	0.00	0.15	0.03	0.11
Eicosadienoic acid (20:2 n6)	0.57	0.96	0.73	0.14	0.30
Dihomo-ɤ-linolenic acid (20:3 n6)	4.82	4.88	4.34	0.34	0.67
SPUFA	15.48	14.45	13.79	0.68	0.83
SMUFA/SSFA	1.10	1.10	1.13	0.05	0.17
SPUFA/SSFA	0.40	0.36	0.36	0.02	0.79
Atherogenicity index	0.73	0.71	0.67	0.03	0.4
Thrombogenic index	1.04	1.05	0.99	0.04	0.46

SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids. Atherogenicity index = [(12:0 + 4(14:0) + 16:0)/[(n-6 + n-3)PUFA + 18:1+otherMUFA). (Ulbricht and Southgate, 1991). Thrombogenic index = (14:0 + 16:0 + 18:0)/[(0.5 × 18:1) + 0.5(MUFA) + 0.5 (n-6PUFA) + 3(n-3PUFA) + (n-3PUFA/n-6PUFA)). (Ulbricht and Southgate, 1991).

energy and protein ratios, this decrease may stem from the enhancement of energy efficiency in 20% olive pomace lambs. Further investigation is necessary to understand the exact mechanisms involved. Ragni et al (11) and Abo Omar et al (27) observed that olive pomace fed lambs had lower (P = 0.05) carcass, pelvic, and kidney fats. However, the inclusion of olive pomace at two levels did not affect carcass ultimate pH (P = 0.75). According to Duarte et al. (28) in unstressed animals the ultimate value of pH usually ranges from 5.5 to 5.8. The average ultimate pH (5.7) obtained from this study is within the normally recommended range (Table 4). Ragni et al. (11) reported similar (P > 0.05) ultimate pH for control (5.7) and destoned olive pomace (5.8) animals. Neither the carcass and leg compactness nor the yield of carcass cuts among treatments differed (P > 0.05, Table 5). The mean values for carcass and leg compactness indices were 24 and 5.3 kg/m, in this study, respectively. High priced joints had higher percentage yield (P = 0.60) in 10% olive pomace fed lambs (61%) than the other diet fed animals (60%). These results collaborated well with those obtained in previous studies using the same genotype (29,30).

In all three animal groups, the fatty acid compositions of LD muscle mirrored what happened to the main fatty acids in all the diets (Tables 3 and 6). In ruminants rumen biohydrogenation determines the fatty acid profile of their meat (31). Palmitic (16:0) and stearic (18:0) acids were the most abundant SFA (33%) in the meat of all animal groups,

Table 7. Effects of dried stoned olive pomace (OP) level on sensory profile of lamb.

Sensory variables	Control	OP10%	OP20%	SEM	P value
Cooking loss	46.78[c]	36.62[a]	40.23[b]	0.62	<0.001
Odor	7.30	7.30	7.80	0.44	0.66
Tenderness	7.00	7.10	7.60	0.38	0.52
Juiciness	6.50	6.90	7.00	0.51	0.77
Aroma intensity	6.60	6.60	7.40	0.42	0.33
Flavor intensity	6.80	7.30	7.40	0.46	0.65
Overall acceptance	7.20	7.70	8.00	0.33	0.24
General remarks	7.30	7.90	8.00	0.37	0.38
Average points	6.96	7.26	7.60	0.33	0.42

without any significant effect from the dietary treatments. However, the 20% olive pomace group contained a lower ($P < 0.05$) percentage of pentadecanoic acid (15:0) than the others (Table 6). This significant decrease may be related to differences in rumen metabolism related to higher MUFA content, mainly oleic acid (18:1), found in this group. In fact, high levels of dietary 18:1 have been effective in lowering some degree of saturation in the rumen and tissue (32,33). Greater deposition of 18:1 was found to increase the vitamin E level in muscle, which is desirable for protecting muscle fat from peroxidation (8). Olive pomace tended ($P = 0.14$) to increase total MUFA in meat (Table 6). The most abundant MUFA in all animal groups was oleic acid (18:1). As expected, a direct relationship was observed between the level of dietary oleic acid and the concentration of oleic acid in the lamb muscle, which is in agreement with most of the literature (5,8,9). However, the inclusion of 220 g/kg (control), 300 g/kg (10%OP), and 360 g/kg (20%OP) oleic acid (18:1) per kg diet lead to a concentration of 340 g, 340 g, and 350 g per kg in the muscle (Tables 1 and 6). This suggests a dose response effect, but the differences in meat oleic acid (18:1) content were smaller than the differences in the diet (8). The reason for the lower transfer of oleic acid (18:1) from diet to muscle may be related to the activity of stearoyl CoA desaturase, which is also possibly parallel to the level of endogenous conjugated linoleic acids in muscle (34). Nevertheless, higher amounts of unsaturated fatty acids and SMUFA/SSFA found in meat from olive pomace diets represent a favorable change in regard to human dietary guidelines (9,35). In addition, lower values for calculated atherogenicity and thrombogenic indices observed in meat from the highest olive pomace (20%) also suggest that oleic acid enriched meat would be of additional benefit to human health (9,35). The level of olive pomace did not affect the percentage of PUFAs in the meat. The most abundant PUFAs were the n6 series (Table 6), which reduce blood lipids (36). However, due to the low concentrations of n3 series PUFAs in the lamb diets, the amount of this fatty acid series in muscle was also poor (37). Nevertheless, in our study the ratio of SPUFA/SSFA (0.39) is acceptable, but further increases are required in muscle PUFA (>0.4) to meet consumers' nutritional guidelines (35,37). There will be improved systems to decrease rumen biohydrogenation and different combinations of dietary fatty acids required in the future (38).

It is often found that meat with a lower water-holding capacity will rapidly lose its juice during cooking. In our research the meat of olive pomace fed lambs retained most of its juice. As a result with less cooking loss the meat would retain its nutritional value (39). It is reported that the three most important sensory attributes for consumers are flavor, tenderness, and juiciness (40). The unsaturated phospholipid fatty acids are particularly important in flavor development. Previously it has been shown that oleic acid, linoleic acid, and linolenic acids are the greatest sources of flavor (41). Indeed our study also found that the highest ratio of unsaturated fatty acids fared best with the panelists, which was found in the 20% olive pomace fed lambs (Table 7). The largest difference in the olive pomace fed lambs was in the aroma and flavor intensity.

With the increasing cost of conventional feeds there will no doubt be increased interest in the possibilities of using by-products. This study showed that in an intensive lamb production system lambs offered dried olive pomace up to 20% of total diet show no depression in slaughter weight and carcass characteristics. The action of olive pomace seems most likely associated with change in fat metabolism with regard to a decrease in fat deposition and modified fat composition of the meat. It appears that olive pomace fed lambs have relatively higher proportions of total unsaturated fatty acids in their LD muscle compared with the standard concentrate. In the view of current interest in Mediterranean-type lamb production

combined with the operation of a national testing scheme aimed at reducing fat content of the carcass, these higher levels of oleic acid in meat of lambs could well become a factor of significance in lamb meat quality.

Acknowledgments
This study constitutes a portion of a project supported by the Republic of Turkey Ministry of Science, Industry and Technology (0342-STZ-2013-2). We acknowledge Kaya Yağcı for supplying and processing the olive pomace and his inputs in this study; Örnek Et Company, Hakan Kırmızıay, and his staff for the technical support in slaughtering and preparing the carcasses; and BursaYem Feed Factory for preparing the experimental diets. We also thank the Center of Agricultural for Teaching and Research staff for their help.

References

1. O'Mara FP. The role of grasslands in food security and climate change. Ann Bot 2012; 110: 1263-1270.
2. Servili M, Esposto S, Taticchi A, Urbani S, Selvaggini R, Di Maio I, Veneziani G. Innovation in extraction technology for improved virgin olive oil quality and by-product valorization. Acta Hortic 2011; 888: 303-316.
3. Meo Zilio D, Bartocci S, Di Giovanni S, Servili M, Chiariotti A, Terramoccia S. Evaluation of dried stoned olive pomace as supplementation for lactating Holstein cattle: effect on milk production and quality. Anim Prod Sci 2015; 55: 185-188.
4. Vasta V, Luciano G. The effect of dietary consumption of plants secondary compounds on small ruminants products quality. Small Rumin Res 2011; 101: 150-159.
5. Mele M, Serra A, Pauselli M, Luciano G, Lanza M, Pennisi P, Conte G, Taticchi A, Esposto S, Morbidini L. The use of stoned olive cake and rolled linseed in the diet of intensively reared lambs: effect on the intramuscular fatty-acid composition. Animal 2014; 8: 152-162.
6. Cabiddu A, Canu M, Decandia M, Pompei R, Molle G. The intake and performance of dairy ewes fed with levels of olive cake silage in late pregnancy and suckling periods. In: Ben Salem H, Nefzaoui A, Morand-Fehr P, editors. Nutrition and feeding strategies of sheep and goats under harsh climates. Centre International de Hautes Etudes Aqronomiques Mediterraneennes-Instituto Agronomico Mediterraneo de Zaragoza (CIHEAM-IAMZ), Zaragoza, Spain; 2004. pp. 197-220.
7. Abbeddou S, Rischkowsky B, Richter EK, Hess HD, Kreuzer M. Modification of milk fatty acid composition by feeding forages and agro-industrial by-products from dry areas to Awassi sheep. J Dairy Sci 2011; 94: 4657-4668.
8. Luciano G, Pauselli M, Servili M, Mourvaki E, Serra A, Monahan MJ, Lanza M, Priolo A, Zinnai A, Mele M. Dietary olive cake reduces the oxidation of lipids, including chlosterol, in lamb meat enriched in polyunsaturated fatty acids. Meat Sci 2013; 93: 703-714.
9. Vera R, Aguilar C, Lira R, Toro P, Barrales L, Pena I, Squella F, Perez P, Quenaya J, Yutronic H, Briones I. Feeding dry olive cake modifies subcutaneous fat composition in lambs, noting cake resistance to degradation and peroxidation. Chil Agric Res 2009; 69: 548-559.
10. Foti F, Capara P, Giuffrida G, Scerra M, Chies L. Olive cake, citrus pulp and wheat straw silage as an ingredient in lamb diets: 2. Effects on meat quality. Ital J Anim Sci 2003; 2: 491-493.
11. Ragni ML, Melodia L, Bozzo F, Colonna MA, Megna V, Toteda F, Vicenti A. Use of a de-stoned olive pomace in feed for heavy lamb production. Ital J Anim Sci 2003; 2: 485-487.
12. Vera R, Aguilar C, Toro P, Squella F, Perez P. Performance of lambs grazing an annual Mediterranean pasture or fed supplements based on olive cake or maize and its influence on system outputs. Animal Prod Sci 2013; 53: 516-522.
13. NRC. Nutrient requirements of Small Ruminants. In: Whitacre PT, editor. Sheep, Goats, Cervids and New World Camelids. 6th ed. Washington, DC, USA: National Academy Press; 2007. pp. 384.
14. AOAC. Official methods of analysis. 16th ed. Arlington, VA, USA: Association of Official Analytical Chemists; 1995.
15. Van Soest PJ, Robertson JB, Lewis B. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. J Dairy Sci 1991; 74: 473-481.
16. Colomer-Rocher F, Delfa R, Sierra I. Method for evaluating sheep carcasses produced in Mediterranean countries. Cuadernos INIA 1988; 17.
17. Greiner SP, Rouse GH, Wilson DE, Cundiff LV, Wheeler TL. Accuracy of predicting weight and percentage of beef carcass retail product using ultrasound and live measurements. J Anim Sci 2003; 81: 466-473.
18. Folch J, Lees M, Sloane-Stanley GH. A simple method for the isolation and purification of total lipids from animal tissues. J Biol Chem 1957; 226: 497-509.
19. Meilgaard M, Civille GV, Carr BT. Sensory evaluation techniques. 2nd ed. Florida, FL, USA: CRC Press; 1991.
20. SAS Institute. A User's Guide to SAS V9.4. Cary, NC, USA: SAS Institute, Inc.; 2005.
21. Tull DS, Hawkins DI. Marketing Research: Measurement and Method. 6th ed. New York, NY, USA: Macmillan Publishing Co; 1994.
22. Molina-Alcaide E, Yanez-Ruiz DR, Moumen A, Martin Garcia AI. Chemical composition and nitrogen availability for goats and sheep of some olive by-products. Small Rumin Res 2003; 49: 329-336.

23. Awawdeh MS, Obeidat BS. Treated olive cake as a non-forage fiber source for growing Awassi lambs: effects on nutrient intake, rumen and urine pH, performance and carcass yield. Asian Australas J Anim Sci 2013; 26: 661-667.

24. Tufarelli V, Introna M, Cazzato E, Mazzei D, Laudadio V. Suitability of partly destoned exhausted olive cake as by-product feed ingredient for lamb production. J Anim Sci 2013; 91: 872-877.

25. Mioc B, Pavic V, Vnucec I, Prpıc Z, Kostelic A, Susıc V. Effect of olive cake on daily gain, carcass characteristics and chemical composition of lamb meat. Czech J Anim Sci 2007; 52: 31-36.

26. Abo Omar JM. Gavoret L. Utilization of olive cake in fattening rations of Awassi lambs. Rev Med Vet 1995; 146: 273-276.

27. Abo Omar JM, Daya R, Ghaleb A. Effects of different forms of olive cake on the performance and carcass quality of Awassi lambs. Anim Feed Sci Technol 2012; 171: 167-172.

28. Duarte MS, Paulino PV, Fonseca MA, Diniz LL, Cavali J, Serao NV, Gomide LA, Reis SF, Cox RB. Influence of dental carcass maturity on carcass traits and meat quality of Nellore bulls. Meat Sci 2011; 88: 441-446.

29. Ekiz B, Yılmaz A, Özcan M, Kaptan C, Hanoğlu H, Erdoğan İ, Yalçıntan H. Carcass measurements and meat quality of Turkish Merino, Ramlic, Kıvırcık, Chios and Imroz lambs raised under an intensive production system. Meat Sci 2009; 82: 64-70.

30. Gökdal O, Atay O, Eren V, Demircioğlu SK. Fattening performance, carcass and meat quality characteristics of Kivircik male lambs. Trop Anim Health Prod 2012; 44: 1491-1496.

31. Harfoot CG, Hazlewood G. Lipid metabolism in the rumen, In: Hobson PN, editor. The Rumen Microbial Ecosystem. London, UK: Elsevier Applied Science Publishers; 1988. pp. 285-322.

32. Miller MF, Shackelford SD, Hayden KD, Reagan J. Determination of the alteration in fatty acid profiles, sensory characteristics and carcass traits of swine fed elevated levels of monounsaturated fats in the diet. J Anim Sci 1990; 68: 1624-1631.

33. Buccioni A, Antongiovanni M, Petacchi F, Mele M, Serra A, Secchiari P, Benvenuti D. Effect of dietary fat quality on C18:1 fatty acids and conjugated linoleic acid production: an in vitro rumen fermentation study. Anim Feed Sci Technol 2006; 127: 268-282.

34. Griinari JM, Corl BA, Lacy SH, Chouinard PY, Nurmela KVV, Bauman DE. Conjugated linoleic acid is synthesized endogenously in lactating dairy cows by DELTA9-desaturase. J Nut 2000; 130: 2285-2291.

35. Enser M, Hallett K, Hewett B, Fursey GAJ, Wood JD. Fatty acid content and composition of English beef, lamb and pork at retail. Meat Sci 1996; 44: 443-458.

36. Ulbricht TL, Southgate DA. Coronary heart disease: seven dietary factors. Lancet 1991; 338: 985-992.

37. Wood JD, Enser M, Fisher AV, Nute GR, Sheard P, Richardson RI. Fat deposition, fatty acid composition and meat quality: a review. Meat Sci 2008; 78: 343-358.

38. Chikunya S, Demirel G, Enser M, Wood JD, Wilkinson RG, Sinclair LA. Biohydrogenation of dietary n-3 PUFA and stability of ingested vitamin E in the rumen and their effects on microbial activity in sheep. Br J Nutr 2004; 91: 539-550.

39. Osório JCS, Osório MTM, Sañudo C. Sensorial characteristics of sheep meat. R Bras Zootec 2009; 38: 292-300 (article in Portuguese with an abstract in English).

40. Robbins K, Jensen J, Ryan KJ, Homco-Ryan C, Mc Keith FK, Brewer MS. Consumer attitudes towards beef and acceptability of enhanced beef. Meat Sci 2003; 65: 271-729.

41. Mottram, DS. Flavor formation in meat and meat products: a review. Food Chem 1998; 62: 415-424.