



Effect of olive pomace as supplement on growth, carcass and meat characteristics of Karadi lambs

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ABSTRACT

This investigation aims to determine the effect of olive pomace on growth performance and quality of carcass characteristics of Karadi lambs. Lambs were grouped by initial body weights (29.746 ± 1.49 kg) and randomly distributed into five groups. While one group received commercial concentrates without olive pomace, the second, third, fourth and fifth groups received an experimental diet containing 4, 8, 12 and 16% of olive pomace, respectively. The lambs' body weight, feed intake and feed conversion ratio were recorded weekly. At 46 kg live body weight, three lambs from each group were slaughtered in order to record carcass and non-carcass characteristics. Lambs fed olive pomace had significantly higher average daily gain and feed conversion ratio than those fed on the control diet. The experimental groups also produced carcass yield mainly due to an increase in carcass weight. Lambs fed 12% olive pomace had significantly higher rib eye area and fat thickness. The wholesale cuts showed that lambs fed olive pomace had significantly higher shoulder and shank percentage and significantly lower loin percentage than those of the lambs fed on the control diet. Most carcass cuts of lambs fed 8% olive pomace recorded significantly higher percentage of lean. Overall, supplementation with olive pomace significantly improved lamb growth and showed its capacity for meat production.

Keywords: Carcass traits, Growth performance, Lamb, Olive by-products

Sheep farming is an activity of economic importance in the world. Increasing added value of sheep meat and its products through sustainable quality and development of named origin and ecological products are mechanisms to support the sheep farming sector, increase the profitability of sheep farmers, and protect local and endangered breeds (De-Arriba and Sanchez-Andres 2014). On the other hand, the current consumer is sensitive to management practices capable of pre-serving local breeds and improving the welfare of animals; and they are available to pay a higher price for certified products with quality seals. Meat quality is a multidimensional concept encompassing organoleptic, nutritional and microbiological characteristics, which are regulated by factors that are intrinsic and extrinsic to the animal (Cadavez *et al.* 2020).

In livestock industry, feed is one of the highest variable affecting the cost of production. Olive pomace is a by-product of olive oil industry and could be considered as a potential livestock feedstuff to be used as an energy supplement and can potentially alter the biochemical

composition of blood and muscle tissue (Urso 2017). The olive oil market is constantly growing and strongly subjected to technological innovation aimed to improve the yield and quality of the final product. As a result, there is an inevitable production of by-products coming from olive oil processing, i.e. olive pomace (European Commission 2021). The valorization of these by-products responds to the strong demand for innovation in food system. Agro-food wastes and by-products represent a suitable matrix to be exploited in food chain (Foti *et al.* 2022). This investigation evaluated the effect of the dietary supplemented olive pomace on performance, carcass characteristics and meat quality of finished Karadi lambs.

MATERIALS AND METHODS

All animals received humane care according to the standard local guidelines. The experimental protocol was approved by the local animal care and use committee of the Agriculture College, Salahaddin University-Erbil, Kurdistan Region, Iraq.

Preparation of olive pomace: Olive pomace, also called, olive cake or olive husk is the solid residue obtained after olive oil extraction. It is one of the most abundant agroindustrial by-products in the Mediterranean area (Neifar *et al.* 2013). Olive pomace used in the present study was obtained from Zamzamin olive oil manufactory (Erbil, Iraq). The olive pomace was dried under the sun, and

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then the dried olive pomace was combined for 5 min with 1 kg of basal feed before being mixed with the authorized feed. The chemical components of olive pomace (based on the dry matter) were 71.5% of dry matter, 3.4% of protein, 3.5% of fat, 43.0% of fibre, 18.96% of non-fiber carbohydrate (NFC), and 2.6% of ash.

Animal management: A total of 35 karadi male lambs aged 4 months with average initial weight of 29.746 ± 1.49 kg were used. The animals were divided into five treatment groups (7 lambs per group) randomly, after 14 days' adaptation period. The lambs in the first group were fed an experimental diet (control diet with no olive pomace). The lambs in the second, third, fourth and fifth group were fed an experimental diet plus 4, 8, 12 and 16% of olive pomace, respectively. The experimental diet was prepared on the basis of the sheep's nutritional system using the Cornell net carbohydrates program and the sheep protein system (CNCPS sheep), Cannas *et al.* (2004) published detailed calculations, and 9.32 MJ/kg DM and dietary protein for rising lambs is reported to be metabolizable energy for this analysis. This study used a ratio of 75% concentrate feed and 25% of wheat straw. All lambs received clean water and fed 3% of body weight as feeding stuffs, twice a day. The formulation and chemical composition of the experimental diet are presented in Table 1.

Growth performance: Average daily intake (ADI), feed intake (FI), average daily gain (ADG), total gain (TG), growth period (GP) and feed conversion ratio (FCR) were recorded and calculated after lambs' weight at initial and weekly interval during whole experiment periods which were needed to achieve 46 kg live body weight per animal (slaughter weight).

Slaughtering and carcass characteristics: When the animal reached 46 kg of live body weight, three lambs for each group were slaughtered after fasting for 12 h prior to slaughter. Prior to slaughter, immediately slaughter body

weight (SBW) was recorded. The slaughter processing was done according to Halal/Islamic slaughter method. After bleeding and evisceration, dressed carcasses were weighed (hot carcass weight; HCW) within 45 min postmortem, chilled at 4°C for 24 h and reweighed (cold carcass weight; CCW). Chilling loss was estimated as the difference between hot and cold carcass weight expressed as percentage. The empty body weight (EBW) was calculated by calculating the difference between the slaughter weight and digested content weight. The dressing out percentage was determined as the proportion of HCW and CCW to the slaughter weight. The weight of non-carcass components was calculated. The dressing out of carcass was calculated following the formula described by Karim and Mahmood (2022). Following the chilling of the carcass, the carcass was split along the vertebral column into two halves by electric saw. The left side of the carcass was cut into eight wholesale cuts and weighed. The area of *Longissimus dorsi* muscle at the 12th rib was measured by a placom digital planimeter. Fat thickness over the midpoint of *Longissimus dorsi* muscle perpendicularly was recorded using Digital Caliper device.

Physical dissection: Eight cuts of the left half carcasses were weighed and dissected completely into lean, fat and bone. The three components were weighed separately to determine their percentages.

Statistical analysis: The experiment's design was entirely random. The parameters were fitted as dependent variables using the SAS Version 9.2 software's generalised linear model (GLM) technique (Statistical Analysis System, SAS Institute Inc., Cary, NC, USA). Duncan's multiple range test was used to determine the significance of variance between the means of the tested parameters. For all claims, the statistical significance level was set at $P \leq 0.05$. The results were presented as mean values with standard error.

Table 1. Ingredients and composition of the experimental diet

Ingredient	T1 0% OP	T2 4% OP	T3 8% OP	T4 12% OP	T5 16% OP
Wheat straw	30.0	26.0	22.0	18.0	14.0
Barley grain ground	35.0	35.0	35.0	35.0	35.0
Corn	10.0	10.0	10.0	10.0	10.0
Soybean meal	10.0	10.0	10.0	10.0	10.0
Wheat bran	10.4	10.4	10.4	10.4	10.4
Olive pomace	0	4	8	12	16
Calcium carbonate	1.0	1.0	1.0	1.0	1.0
Minerals and vitamins premix	1.5	1.5	1.5	1.5	1.5
Salt	0.6	0.6	0.6	0.6	0.6
Sodium bicarbonate	1.5	1.5	1.5	1.5	1.5
Total	100	100	100	100	100
<i>Chemical composition of experimental feeds % DM</i>					
Crude protein (CP)	13.7	13.7	13.7	13.7	13.7
Neutral detergent fiber (NDF)	37.1	35.7	34.2	32.8	31.3
Non-fiber carbohydrate (NFC)	39.5	41.0	42.5	43.9	45.4
Ash	9.3	9.1	8.9	8.7	8.5
Fat	2.4	2.4	2.5	2.5	2.6
Metabolizable energy Mcal/kg DM	2.158	2.201	2.244	2.262	2.340

Table 2. Effect of olive pomace on growth performance of Karadi lambs

Parameter	Treatment					SEM	P-value
	T1	T2	T3	T4	T5		
IBW (kg)	29.733	29.976	29.477	29.664	29.881	0.62	0.9994
FBW (kg)	46.143	46.500	46.500	46.214	46.714	0.82	0.9996
TBWG (kg)	16.410	16.524	17.023	16.550	16.833	0.46	0.9948
ADG (kg)	0.260 ^b	0.295 ^{ab}	0.304 ^{ab}	0.338 ^a	0.343 ^a	0.01	0.0458
FP days	63 ^a	56 ^b	56 ^b	49 ^c	49 ^c	0.89	<.0001
SI (kg/d)	0.353 ^a	0.306 ^b	0.252 ^c	0.174 ^d	0.134 ^c	0.01	<.0001
CI (kg/d)	0.822 ^c	0.883 ^b	0.917 ^a	0.824 ^d	0.862 ^c	0.01	<.0001
TFI (kg/d)	1.175 ^b	1.189 ^a	1.170 ^c	0.998 ^d	0.996 ^c	0.01	<.0001
FCR (kg/kg)	4.613 ^a	4.212 ^a	3.977 ^a	3.002 ^b	2.955 ^b	0.15	0.0002

^{a,c} Means within the same row for each parameter with different superscripts are significantly different ($P \leq 0.05$). SEM-Standard error of mean; IBW, Initial body weight; FBE, Final body weight; TBWG, Total body weight gain; ADG, Average daily gain; FP, Feed period; SI-Straw intake; CI, Concentrate intake; TFI, Total feed intake; FCR, Feed conversion ratio. T1-0% olive pomace, T2-4% olive pomace, T3-8% olive pomace, T4-12% olive pomace, T5-16% olive pomace.

RESULTS AND DISCUSSION

Growth performance: Live weight is a good indicator of development and accurately predicts the amount of attractive food components like muscles. One of the most essential criteria of feedlot performance is daily weight gain, which is obviously a desirable husbandry and economic goal in fat lamb production (Archer *et al.* 1999). A number of factors could affect weight gain

including breed, age, fattening phase, sex and diet (Irshad *et al.* 2013). Table 2 shows the effect of the dietary partial olive pomace supplementation on growth performance of lambs. The initial weight, final weight and total body weight gain weight of karadi lambs did not differ between all experimental treatments. However, the result of average daily gain showed that there were significant differences ($P \leq 0.05$) between control group and the fourth and fifth

Table 3. Effect of olive pomace supplementation on carcass and non-carcass characteristics of Karadi lamb

Parameter	Treatment					SEM	P-value
	T1	T2	T3	T4	T5		
SW (kg)	46.333	46.333	46.333	46.333	46.000	0.87	1.0000
DSC (kg)	7.480 ^b	6.737 ^c	7.127 ^{bc}	7.937 ^a	7.513 ^b	0.32	0.8703
EBW (kg)	38.853	39.597	39.207	38.397	38.487	0.69	0.9880
HCW (kg)	20.370 ^c	21.777 ^b	21.633 ^b	21.720 ^b	23.413 ^a	0.49	0.0483
CCW (kg)	19.553 ^c	20.700 ^{cb}	21.717 ^{ab}	21.467 ^{ab}	22.767 ^a	0.59	0.0494
DP ¹ %	43.966 ^c	47.001 ^b	46.718 ^b	46.863 ^b	50.904 ^a	0.75	0.0485
DP ² %	42.202 ^d	44.665 ^{dc}	47.578 ^{ab}	46.315 ^{bc}	49.498 ^a	1.00	0.0168
DP ³ %	52.436 ^c	55.00 ^{bc}	55.231 ^{bc}	56.552 ^b	60.857 ^a	0.85	0.0091
DP ⁴ %	50.331 ^c	52.256 ^c	56.234 ^b	55.889 ^b	59.177 ^a	1.11	0.0235
REA, cm ²	9.721 ^b	10.302 ^b	9.764 ^b	13.270 ^a	9.850 ^b	0.54	0.0508
FT, mm	0.710 ^c	1.133 ^b	1.150 ^b	1.332 ^a	1.064 ^b	0.07	0.0136
Head ⁵	5.675 ^a	4.986 ^b	4.292 ^c	4.341 ^c	4.978 ^b	0.19	0.0408
Feet ⁵	2.655 ^a	2.366 ^b	2.474 ^{ab}	2.467 ^{ab}	2.265 ^b	0.13	0.0345
Skin ⁵	11.405 ^a	10.368 ^b	9.344 ^c	9.682 ^{bc}	9.972 ^b	0.33	0.0160
Liver ⁵	1.535 ^{ab}	1.343 ^c	1.503 ^b	1.475 ^{bc}	1.353 ^c	0.03	0.0197
Heart ⁵	0.409	0.392	0.407	0.406	0.405	0.01	0.9833
Kidneys ⁵	0.264	0.266	0.264	0.241	0.271	0.004	0.2915
Spleen ⁵	0.166 ^c	0.165 ^c	0.178 ^{bc}	0.274 ^a	0.205 ^b	0.01	0.0509
Lungs ⁵	1.295 ^{bc}	1.238 ^c	1.423 ^{ab}	1.502 ^a	1.408 ^{ab}	0.04	0.0444
Testicle ⁵	0.448 ^{bc}	0.506 ^b	0.393 ^c	0.357 ^c	0.616 ^a	0.03	0.0126
Stomach ⁵	3.247 ^a	3.135 ^a	2.843 ^a	3.246 ^a	2.225 ^b	0.15	0.0155
Intestine ⁵	4.863 ^a	4.878 ^a	4.624 ^a	5.018 ^a	3.451 ^b	0.23	0.0484

^{a,d} Means within the same row for each parameter with different superscripts are significantly different ($P \leq 0.05$). SEM-Standard error of mean; T1-0% olive pomace, T2-4% olive pomace, T3-8% olive pomace, T4-12% olive pomace, T5-16% olive pomace. SW, slaughter weight; DSC, digestive system content; EBW, empty body weight; HCW, hot carcass weight; CCW, cold carcass weight; REA, rib eye area; FT, Fat thickness. ¹Dressing percentage = hot carcass weight/slaughter weight $\times$ 100. ²Dressing percentage = cold carcass weight/slaughter weight $\times$ 100. ³Dressing percentage = hot carcass weight/ empty body weight $\times$ 100. ⁴Dressing percentage = cold carcass weight/ empty body weight $\times$ 100. ⁵As a % of slaughter weight.

group which were supplemented with 12 and 16% of olive pomace, respectively. Moreover, the animals in the fourth and fifth group which were supplemented with 12 and 16% of olive pomace had lower feed intake and shorter period to get slaughter weight. This could be due to olive pomace being a good source of energy and diet with high energy content may reduce the animals' total feed intake. These results were similar to those noticed by Sucu *et al.* (2018) who reported that the initial weight and the slaughter weight of lambs were not affected by olive pomace levels. On the other hand, Awawdeh and Obeidat (2013) stated 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.

Carcass and non-carcass characteristics: The carcass and non-carcass traits values of lambs fed diet supplemented with different levels of olive pomace are cleared in Table 3. There were no significant differences in terms of empty body weight between treatment groups,

while the content of digestive system was significantly high ($P \leq 0.05$) in treatment four as compared to the other groups. The values of hot carcass weight and dressing percentage differed significantly ($P \leq 0.05$) between control group and diet five group, but did not differ among other diet groups. This variance among the diet groups may be attributed to the difference of slaughter body weight. The higher lamb carcass yield is an indicator for their significant efficiency and ability for meat production (Sen *et al.* 2011). Similarly, Ragni *et al.* (2003) found greater dressing percentages of lambs fed diet content with 20% stoned olive pomace. Also, Tufarelli *et al.* (2013) reported that a greater carcass weight and dressing percentage were obtained from lambs fed diet supplemented with 10% stoned olive pomace.

Rib eye area is the most important carcass characteristic because of its value in predicting the carcass lean yield, and varies according to breed, sex, body weight, condition and plane of nutrition (Hegarty *et al.* 2006). Also, measurement of subcutaneous fat thickness over muscle particularly

Table 4. Effect of olive pomace supplementation on whole sale cuts and their tissue distribution (%) of Karadi lamb

Parameter ¹		Treatment					SEM	P-value
		T1	T2	T3	T4	T5		
Leg		36.663	36.527	37.487	37.392	37.089	0.42	0.6767
	Lean	0.42	0.6767	71.033 ^a	66.906 ^b	64.348 ^c	0.64	0.0012
	Bone	21.165 ^{ab}	19.956 ^{bc}	21.635 ^a	21.016 ^{ab}	18.690 ^c	0.32	0.0031
	Fat	12.462 ^b	12.716 ^b	7.331 ^c	12.079 ^b	16.962 ^a	0.83	<.0001
Shoulder		17.999 ^b	18.582 ^{ab}	19.283 ^a	19.895 ^a	20.261 ^a	0.57	0.0474
	Lean	71.536 ^b	68.291 ^c	74.130 ^a	72.838 ^{ab}	71.950 ^b	0.56	0.0007
	Bone	21.949 ^b	23.637 ^a	20.342 ^c	20.134 ^c	19.326 ^c	0.44	0.0006
	Fat	6.515 ^{cd}	8.072 ^{ab}	5.528 ^d	7.028 ^{bc}	8.725 ^a	0.33	0.0007
Neck		6.049	7.310	7.099	6.401	6.778	0.22	0.1812
	Lean	64.141 ^c	64.808 ^{cb}	67.112 ^a	66.468 ^{ab}	68.397 ^a	0.48	0.0093
	Bone	31.155 ^a	30.944 ^a	30.633 ^a	31.158 ^a	28.426 ^b	0.33	0.0148
	Fat	4.705 ^a	4.248 ^b	2.255 ^d	2.375 ^d	3.176 ^c	0.26	<.0001
Rank		13.856	12.364	11.404	12.221	12.114	0.63	0.5214
	Lean	64.712 ^c	63.813 ^c	70.524 ^a	68.334 ^b	69.429 ^{ab}	0.72	<.0001
	Bone	28.064 ^b	30.042 ^a	23.436 ^d	25.157 ^c	24.085 ^{cd}	0.68	<.0001
	Fat	7.223 ^a	6.144 ^{ab}	6.040 ^b	6.509 ^{ab}	6.486 ^{ab}	0.16	0.0163
Shank		5.265 ^b	5.880 ^a	5.714 ^a	5.562 ^a	5.429 ^a	0.09	0.0976
	Lean	55.557 ^b	59.713 ^a	54.756 ^b	55.541 ^c	55.353 ^b	0.73	<.0001
	Bone	41.514 ^a	35.341 ^c	39.926 ^b	36.551 ^c	35.492 ^c	0.72	<.0001
	Fat	2.929 ^d	4.946 ^c	5.317 ^c	7.908 ^b	9.155 ^a	0.60	<.0001
Loin		8.888 ^a	7.119 ^b	7.244 ^b	6.813 ^b	6.747 ^b	0.29	0.0222
	Lean	66.078 ^{bc}	70.719 ^a	65.278 ^c	66.958 ^b	70.168 ^a	0.61	<.0001
	Bone	23.962 ^a	21.845 ^b	23.980 ^a	21.668 ^b	19.982 ^c	0.43	<.0001
	Fat	9.960 ^a	7.436 ^b	10.742 ^a	11.374 ^a	9.850 ^a	0.41	0.0040
Breast		8.798	9.411	9.425	8.962	8.790	0.33	0.4019
	Lean	56.915 ^b	61.973 ^a	59.601 ^a	59.681 ^a	54.007 ^c	0.79	0.0005
	Bone	21.223 ^a	21.277 ^a	20.285 ^a	19.292 ^{ab}	18.126 ^b	0.39	0.0175
	Fat	21.862 ^b	16.751 ^d	20.114 ^c	21.027 ^{bc}	27.867 ^a	0.97	<.0001
Flank		2.481	2.807	2.343	2.803	2.792	0.16	0.1243
	Lean	80.811 ^b	78.794 ^c	84.661 ^a	83.971 ^a	80.363 ^{bc}	0.63	<.0001
	Fat	19.189 ^b	21.206 ^a	15.339 ^c	16.029 ^c	19.637 ^b	0.62	0.0002

^{a-d}Means within the same row for each parameter with different superscripts are significantly different ($P \leq 0.05$). SEM-Standard error of mean. T1-0% olive pomace, T2-4% olive pomace, T3-8% olive pomace, T4-12% olive pomace, T5-16% olive pomace.¹As a % of chilled carcass weight excluding fat tail.

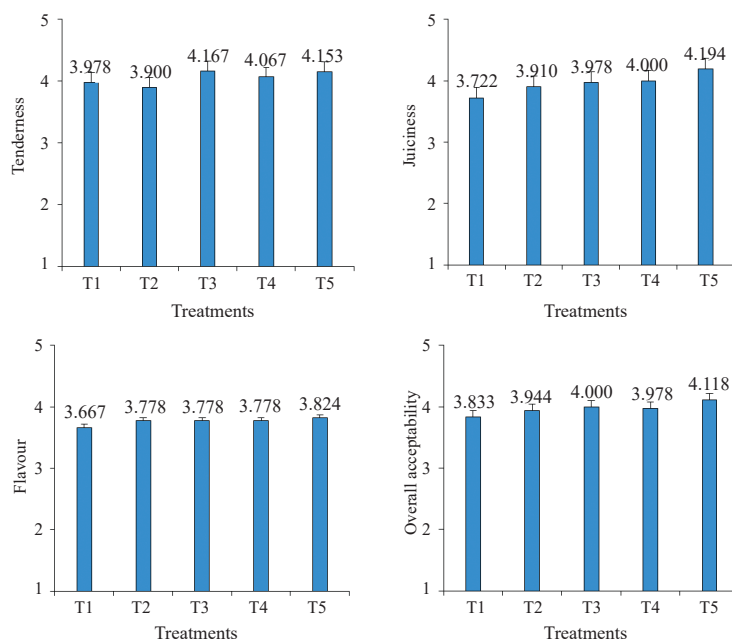


Fig.1. Effect of olive pomace supplementation on sensory meat quality parameters in lambs.

when the rib eye muscle provides a suitable base in the rib and in the loin areas, proved to be one of the valuable techniques for predicting carcass composition and for giving standards on which quality payments are based (de Vargas Junior *et al.* 2021). In the current study, the rib eye area and fat thickness were significantly different between treatment diet groups and carcass obtained from animal in treatment four had high value of rib eye area and fat thickness than those from the other treatment groups (Table 3). However, these results disagree from that presented by Sucu *et al.* (2018), who observed no impact of dried stoned olive pomace on rib muscle area and fat thickness.

With regards to the effect of olive pomace on non-carcass characteristics it seems from Table 3 that there was impact of dried olive pomace on non-carcass characteristics and a difference in the measurements was to be expected. Data showed lower percentage of most non-carcass measurements including head, feet, skin, liver, heart, stomach and intestine in olive pomace fed lambs (4, 8, 12 and 16% of olive pomace, respectively) compared to the control animals.

Wholesale cuts and their tissue distribution: The production of heavier carcasses with acceptable quality for consumers could undoubtedly be advantageous for producers by providing higher profits from meat sales and for consumers by supplying more mature meat with better flavour (Skapetas *et al.* 2006). But the commercial success of systematic lamb fattening is related with carcass traits and composition (Oramari *et al.* 2014). The treatment effects on loin, shoulder and shank carcass cuts which are summarized in Table 4. When cuts are expressed as a percentage of chilled carcass weight, it was found that carcasses obtained from lambs fed olive pomace had significantly higher proportion of shoulder as well as shank

and significantly lower proportion of loin than those of the lambs fed on the control diet.

Throughout life, the adaptation of the body structure of an animal for the efficient physiological function is necessary for survival and is associated with a notable constancy in relative proportions of skeletal and muscular development in different regions of the body as animal grow larger (Atti *et al.* 2004). Furthermore, features of major concern in the growth of the meat producing animal are rate of muscle growth and the relative rates of fat deposition and bone growth. The carcass is composed of different proportions of muscle, fat and bone. Muscle being more edible, is usually regarded as the most important tissue to the consumer (Yáñez *et al.* 2007). Carcass tissue distribution is affected by many factors including stage of maturity, breed, body size, sex and nutrition (Warmington and Kirton 1990). The effect of olive pomace inclusion in the diet on the proportion of separable carcass tissue of lamb carcass cuts is summarized in Table 4. It appears that lean percentage of lambs fed 8% olive pomace was significantly higher in the leg, shoulder, neck, rack, breast and flank cuts. Additionally, muscle content varied according to its location in the carcass. For example, the higher muscle content was in the shoulder (74.130%), whereas the lowest was in the fore shank (54.756%) and the breast (59.601%) in 8% olive pomace fed lamb. The variation in mass of muscle is primarily attributed to differences in the total number of muscle fiber.

Sensory acceptability: Meat flavour characteristics are often regarded as crucial elements for customer acceptance, and they are influenced by a range of factors, including Feedlotting (Alves Cirne *et al.* 2018). Tenderness, juiciness and flavour are the most important factors for panellists (Lopez-Pedrouso *et al.* 2020). The meat of olive pomace fed lambs presented high sources of sensory quality values

than those from the control group although the values were not significant (Fig.1). This finding is in tandem with those of Sucu *et al.* (2018) who reported similar scores of tenderness, juiciness and flavour in meat samples from lambs who received commercial concentrates without olive pomace and lambs who received an experimental diet containing 4, 8, 12 and 16% olive pomace, respectively.

It may be concluded that diet supplementation of olive pomace increased average daily gain and improved feed conversion ratio in lambs. Furthermore, dried olive pomace enhanced the carcass measurements of lamb including carcass weight and yields.

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