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Effects of Slaughter Weight on Growth Performance, Carcass Characteristics, and Fatty Acid Composition of Afshari Male Lambs

Research Article

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ABSTRACT

This study aimed to investigate the difference in growth performance and carcass characteristics of lambs slaughtered at 56, 84, 112, and 140 days of age. Thirty-two male fat-tailed Afshari lambs, with an initial body live weight of 30.2 ± 3.6 (SD) kg and an average age of 90 ± 15 (SD) days, were used in this study. The lambs were equally and randomly distributed in 4 groups. The experiment was conducted in four periods, including 56, 84, 112, and 140 days, and the nutrient requirements of lambs in each period were determined using NRC 2007. At the end of each period, four lambs were randomly chosen and slaughtered, and longissimus thoracic muscle (LT) sampled. The results showed that by increasing the weight of slaughter, dry matter intake (DMI), feed conversion ratio (FCR) (i.e., kg DM/kg gain), and empty body weight increased, but empty digestive tract decreased linearly. The side carcass cuts (neck, shoulder, brisket-flank, rack-loin, and leg) were unaffected by slaughter weight. By increasing the slaughter weight, backfat thickness, LT area increased, and the percentage of dressing, tail fat, and internal fat also increased linearly. As the slaughter weight increased, the ratio of total unsaturated fatty acids to saturated fatty acids (UFA/SFA) decreased in LT fat, but that ratio increased in LT muscle linearly.

KEY WORDS Afshari breed, backfat thickness, carcass cuts, longissimus thoracic muscle, slaughter age.

INTRODUCTION

The increase in the world population will cause a possible increase in the demand for protein sources, including the meat of ruminant animals (Godfray *et al*. 2010), which mainly contains fatty acids, specially saturated fatty acids (SFA), which are related to the occurrence of cardiovascular diseases in human. For this reason, there is an increasing interest in consuming lean and low-fat meat (Karami *et al*. 2013). Many people in the world are more interested in mutton than beef. Mutton is an essential source of high-quality protein, fat, and bioactive micronutrients, including iron, zinc, and B vitamins (Prache *et al*. 2022). New evidence has shown that, like the meat of other ruminants, sheep meat is a significant source of polyunsaturated fatty acids (PUFA) and some biohydrogenation intermediates, such as ruminic acid and trans vaccenic acid, which have potentially beneficial effects on human health (Chikwanha *et al*. 2018; Vahmani *et al*. 2020). In Iran, the main goal of sheep breeding is the production of high-quality carcasses in terms of meat percentage, containing low levels of SFA and high levels of UFA, especially. The published reports indicate that factors such as rearing system (grazing in the pasture or manual feeding with concentrate), ration, and age at the time of slaughter changed the carcass composition (Diaz *et al*. 2002; Mashele *et al*. 2017; Uushona *et al*. 2023). It has been shown that by increasing the live weight of lambs, the amount of carcass fat and fat thickness in-

creases (Fourie *et al*. 1970; Wood *et al*. 1980; Black, 1983). In general, lambs with lower weights at any stage of maturity will have a lower fat ratio (Kempster and Cuthbertson, 1977; Wood *et al*. 1980; Kirton *et al*. 1995). In addition, the level of fatness also affects the fatty acid composition of meat. By increasing the fat ratio in the carcass, the contents of SFA and monounsaturated fatty acids (MUFA) increased faster than the amount of PUFA (De Smet *et al*. 2004).

The carcass characteristics of lamb produced in Iran differ from most other countries. More than 10 million male lambs are slaughtered in Iran every year. So, the main part of the red meat of small ruminants is provided by lambs (Agricultural Statistics, 2022). The economic performance of sheep farms in Iran is not satisfactory for various reasons, including the misunderstanding of many sheep farmers about appreciating the time of fattening lamb slaughter (Papi, 2008).

In Iran, the length of lamb fattening time is one of the things that has received less attention from ranchers. Therefore, ranchers, based on the wrong practices of the past, keep male lambs until they are entirely fatness. In this case, in addition to reducing the income, due to the rise of feed conversion ratio and decrease in the growth of the animal's body, the carcasses are not marketable due to high-fat content.

Most research done on Iranian native sheep has been done to determine the appreciative length of the fattening period (Dadpasand and Izadifard, 2009; Mousavi *et al*. 2011; Talebi, 2013). So, there is little information about the composition of carcasses of slaughtered lambs with different weights. Therefore, the present study was designed with the aim of determining the optimal slaughter weight of male fat-tailed Afshari lambs.

MATERIALS AND METHODS

Study site and time

The study started in the autumn of 2022 at the Sheep Research Station of the Animal Science Research Institute of Iran, located in Karaj City, Alborz province, and ended in the spring of 2023. Karaj is located at an altitude of 1312.5 m above sea level (latitude: 35˚ 56′ N, Longitude: 50˚ 58′ E). The average annual temperature and rainfall in this area are 14.1 ˚C and 265 mm.

Preparation of diets

The experimental diets were formulated according to the nutrient requirements of small ruminants (NRC, 2007) and consisted of four rations based on animal weight (d1, d2, d3, and d4). The diets were used from the beginning to the 56th days, 57 to 84th days, 85 to 112th days, and 113 to 140th days of the experiment (Table 1).

The chemical composition of ingredients was measured by laboratory methods (AOAC, 2002), and to calculate metabolizable energy (ME), Nutrient Tables of Iranian Feedstuffs were used (Gholami *et al*. 2017).

Animal management

Lambs were randomly divided into four equal categories and housed in groups pen (20 m^2 of floor space), and fed twice daily, at 08:00 and 16:00. They had free access to fresh and clean water. All lambs were individually weighed on the days 1, 14, 28, 42, 56, 70, 84, 98, 112, 126, and 140 at 08:00 h after 16 h feed privation. Individual feed intake was recorded by subtracting the weight of the daily offered feed from refused quantities for each animal group (1-56 days; n=8, 57-84 days; n=7, 85-112 days; n=6, and 113-140 days; n=5) and dividing it by 8, 7, 6, and 5, respectively. The average daily gain (ADG) of each lamb was determined by adding the average daily gain for each two-weeks period. Each lamb's feed conversion ratio (FCR) was determined by dividing its daily DM intake by its ADG.

Slaughter procedures

During the experiment, on days 56, 84, 112, and 140, 16 lambs were chosen and slaughtered by exsanguination using standard human methods. The lambs were weighed following a 16-hour feed deprivation period and had access to clean fresh water (4 lambs from each occasion). These lambs were close to the mean body weight of their group. External organs like the head, feet, and skin were removed from the body and weighed after the animal was slaughtered and all blood had been completely removed.

The internal organs, including the liver, heart, lungs, kidneys, spleen, kidney-pelvic-gut fat, and digestive system, were removed from the corpses after they had been dissected and weighed. Additionally, when the digestive system was cleared, the contents were weighed. Empty body weight was determined by deducting the slaughter weight from the contents of the digestive system.

The hot carcasses were weighed and chilled at +4 ˚C for 24 h. The cold carcasses were weighed and then sawed along the backbone into two symmetrical sides. The right-side carcasses were cut into six large-scale cuts (neck, shoulder, leg, rack-loin, brisket-flank, and tail fat) and weighed separately (Papi *et al*. 2011). On the left side of the carcass, between the 12th and 13th ribs, the loin eye muscle area was measured, and a planimeter (Model KP-25, USA) was used to measure the cross-section area. The backfat thickness of half the left carcass measured on the deepest part of the loin-eye muscle.

Fatty acids profile

On the left side of every carcass, the longissimus thoracic muscle (LT) was excised, situated between the 12th thoracic and the fifth lumbar vertebrae. Samples' fat and muscle were separated. Up to the fatty acid profiles subsequent measurement, all samples were frozen at -20 ˚C. Following Folch *et al*. (1957) description, total fatty acids were extracted from fat and muscle samples using a chloroform–methanol solvent extraction technique. In brief, 20 mL of a 2:1 (v/v) chloroform/methanol mixture with 1 g of homogenized material (fat or lean) was mixed. Before drying the extract under nitrogen, an internal standard of heneicosanoic acid (C21:0, Sigma Co., St. Louis, MI, USA) was applied. In gas chromatography, the fatty acid methyl ester (FAME) was produced and kept in screw-capped vials coated with Teflon at 4 ˚C (Model 6890, Agilent Technologies, USA). Fatty acids were identified using the method outlined by Karami *et al*. (2011) after the FAME was separated on a Supelco SP-2330 (Supelco, Inc., Bellefonte, PA, USA) fused silica capillary column (60 m, 0.25 mm ID, 0.20 Inc., Bellefonte, PA, USA).

Statistical analyses

The statistical model for data analysis was:

$$Y_{ij} = \mu + T_i + \beta(w_i\text{-}w) + e_{ij}$$

Where:

Y_{ij}: controlled trait of *ij*-lamb.

μ: mean of the trait.

T_i: effect of treatment (length of fattening period).

$\beta(w_i\text{-}w)$= linear regression function coefficient of the studied trait from the test start weight.

e_{ij}= residual error connected with the ij-th observation.

Data on growth performance and carcass characteristics were analyzed as a completely randomized design. Treatment means were generated using the least-square means procedure of SAS and separated using the LSD test. For all the data, animal was used as the trait unit, and the data was reported significant at ≤ 0.05. Analysis of variance performed using SAS version 9.1 statistical software (SAS, 2002). The SAS program's polynomial contrasts statement was used to get animal responses that were linear, quadratic, and cubic with the duration of the fattening phase.

RESULTS AND DISCUSSION

Dry matter intake (DMI), average daily gain (ADG), and feed conversion ratio (FCR) of lambs are presented in Table 2.

Dry matter intake increased linearly with the increasing slaughter age. With the increase in the slaughter age, ADG rose until day 56, then it began to decrease. Feed conversion ratio responded linearly to increasing the slaughter age, in which the most efficient observed in the first weight recording and the least efficient was observed in the last.

Slaughter information of lambs at different ages is presented in Table 3. As the slaughter age enhanced, the slaughter weight, empty body weight, and hot and cold carcass weight increased linearly (L=0.001). The percentage of digestive contents and empty digestive tract decreased linearly (L=0.001) with the increasing slaughter age. The percentage of offal parts (blood, head, feet, liver, lung, and spleen) decreased with the increase of slaughter weight linearly (L=0.001), but skin and kidney were not affected. There was a cubic response (C=0.05) for the heart. However, with increasing slaughter weight, a linear increase (L=0.001) in visceral fat (kidney-pelvic-gut fat) was observed.

The carcass characteristics of lambs at different slaughter weights are given in Table 3. With the increased live weight at slaughter, side carcasses, including neck, shoulder, brisket-flank, back-loin, leg and tail fat weights increased linearly (L=0.001). However, the percentage of neck, shoulder, brisket-flank, back-loin, and leg, were not affected, except tail fat, that increased linearly (L=0.001). Dressing percentage, backfat thickness, and longissimus thoracic muscle area increased linearly as the slaughter weight enhanced. The eye muscle area increased with the slaughter weight linearly (L=0.002).

The results of the fatty acids composition of LT muscle (fat and muscle) are shown in Table 4. By increasing the slaughter weight, the percentage of caproic (C6:0), caprilic (C8:0), caprinic (C10:0), stearic (C18:0), oleic (C18:1), and arachidid (C20:0) acids in LT muscle, were not affected by the slaughter weight. Lauric (C12:0), myristic (C14:0), myristoleic (C14:1), palmitic (C16:0), and palmitoleic (C16:1) acids decreased with increasing slaughter weight of fattening lambs linearly (l=0.01), but linoleic acid (18:2) increased. The total SFA in LT muscle decreased, but the total UFA increased as the weight of lambs gained linearly (L=0.01). As the slaughter weight increased, a linear and cubic change in USA/SFA ratio was observed (L & C=0.01).

C6:0, C10:0, C18:2, and C18:1 trans values in LT muscle fat were not affected by increasing the weight of lambs, but C14:0, C14:1, and C20:0 values increased with enhancement of the slaughter weight (L=0.01). When slaughter weight increased, the SFA in LT muscle fat increased, while the UFA decreased linearly (L=0.04). A linear decline was observed in the UFA/SFA ratio when laughter weight increased.

Table 1 Ingredients and chemical composition of the experimental diets (DM basis)

Ingredient (g/kg DM)	Experimental diets[1]			
	day 56	day 84	day 112	day 140
Alfalfa hay 14.28% CP	400	200	150	100
Wheat straw	0.00	100	120	200
Barley grain	125	150	140	140
Corn grain	200	200	200	200
Wheat grain	75	100	154	154
Wheat bran	100	172	178	178
Soybean meal 43% CP	75	50	0.00	0.00
Mineral and vitamin mix[2]	5.0	5.0	5.0	5.0
Salt	3.0	3.0	3.0	3.0
Bicarbonate sodium	8.0	10.0	10.0	10.0
Limestone	9.0	10.0	10.0	10.0
Chemical composition (g/kg)				
Crude protein	146	128	109	103
Metabolizable energy (MJ/kg)	11.7	11.7	11.4	11.3
Calcium	11.7	10.6	8.6	8.0
Phosphorus	3.6	3.7	3.7	3.6

[1] day 56, day 84, day 112, and day 140 refer to diets used until days 56, 84, 112, and 140 of the experiment, respectively.
[2] 1 kilogram of mineral and vitamin mix contains: vitamin A: 500000 IU; vitamin D: 100000 IU; vitamin E: 100 IU; Mg: 2000 mg; Zn: 3000 mg; Mn: 3000 mg; Fe: 3000 mg; Cu: 300 mg; Co: 100 mg; I: 100 mg and Se: 1 mg.

Table 2 Dry matter feed intake, average daily gain and feed conversion ratio in Afshari male lambs

Item	Experimental period[1]				SEM	Contrasts[2]		
	1-56	57-84	85-112	113-140		L	Q	C
No	32	28	24	20				
Initial body weight (kg)	29.0^{a}	44.8^{b}	52.8^{c}	58.4^{d}	2.91	0.001	0.002	0.366
Final body weight (kg)	44.8^{c}	52.8^{b}	58.4^{a}	62.6^{a}	1.83	0.001	0.205	0.884
Average daily gain (g)	282^{a}	289^{a}	197^{b}	159^{b}	1.16	0.001	0.149	0.035
Dry matter intake (g/day)	1139^{c}	1549^{b}	1792^{a}	1965^{a}	84.45	0.001	0.071	0.729
Feed conversion ratio (kg DM/kg gain)	4.1^{b}	5.6^{b}	9.4^{a}	13.3^{a}	1.00	0.001	0.227	0.647

[1] 1-56 days, 57-84 days, 85-112 days, and 113-140 days refer to date of experiment that lambs weighed.
[2] L: linear; Q: quadratic and C: cubic.
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 trend of increasing feed consumption is expected because it is associated with the increasing trend of ADG. The trend of increasing DMI of finishing male lambs during the experiment can be attributed to the growth of the body organs and, as a result, their nutritional requirements (NRC, 2007). The animals mainly consume feed to meet energy requirements (Haddad and Nasr, 2007). Therefore, as the body weight animals gain, the requirements of energy and, consequently DMI increase. In confirmation of the results of the present study, Talebi (2013) reported that with the aging of Lori-Bakhtiari male lambs, from 75 to 105 days, DMI increased. The range of ADG of Afshari male lambs fattened in different experiments (n=16; Ebrahimi *et al.* 2020) and different fattening periods reported to be between 67.7 to 479 g (mean=238 g), which correspond to the ADG of lamb in the present study (240 g).

The lower FCR at the beginning of the fattening period shows that young animals have higher digestibility and faster growth rate (Talebi, 2013).

In a meta-analytical study (Ebrahimi *et al.* 2020) including 16 experiments, the range of FCR of Afshari male lambs was reported to be between 3.6 to 21.5 (mean=7.3), which was consistent with our finding (7.3). In addition, other researchers have also reported that with the aging of native Iranian male lambs, FCR increases (Norollahi, 2007; Dadpasand and Izadifard, 2009).

The increase in the dressing percentage at the end of the fattening period can be due to the decrease in the contents of the digestive tract (Table 3), which occurred with the lengthening of the fattening period. More digestible diets create less gut fill and greater carcass yields (Somasiri *et al.* 2015).

According to Santos Silva and Vaz Portugal (2001), the dressing percentage was higher in unweaned lamb's live body weight (16 kg) than those having 35 kg, mainly due to the rapid weight increase of gastric compartments and intestines that resulted from lamb weaning and the consequent increase in solid feed intake.

Table 3 Effects of slaughter age on carcass characteristics of Afshari male lambs

Item	Experimental period[1]				SEM	Contrasts[2]		
	day 56	day 84	day 112	day 140		L	Q	C
Slaughtering data								
Slaughter weight (kg)	41.6^{c}	46.9^{c}	54.4^{b}	61.7^{a}	2.14	0.001	0.61	0.78
Digestive contents (kg)	4.9	4.7	5.0	4.8	0.14	0.950	0.98	0.46
Digestive contents (%)	11.8^{de}	10.0^{cd}	9.2^{bc}	7.7^{ab}	0.46	0.001	0.83	0.49
Empty digestive tract (kg)	3.3^{bc}	3.7^{b}	4.1^{ab}	4.0^{ab}	0.12	0.002	0.22	0.45
Empty digestive tract (%)	8.0^{b}	7.8^{b}	7.6^{b}	6.4^{a}	0.19	0.002	0.09	0.48
Empty body weight (kg)	38.3^{bc}	43.2^{bc}	50.3^{b}	57.8^{ab}	2.05	0.001	0.49	0.83
Hot carcass weight (kg)	21.7^{c}	24.3c	28.4^{b}	34.1^{a}	1.28	0.001	0.18	0.96
Cold carcass weight (kg)	21.3^{c}	23.7^{c}	27.8^{b}	33.4^{a}	1.26	0.001	0.15	0.97
Dressing percentage (%)[3]	51.2^{b}	50.6^{b}	51.0^{b}	54.2^{a}	0.43	0.003	0.01	0.48
Back fat thickness (mm)	4.80^{cd}	5.80^{c}	7.80^{bc}	10.93^{a}	0.72	0.001	0.25	0.97
Eye muscle area (cm^2)	12.38^{b}	13.00^{b}	13.33^{b}	17.13^{a}	0.67	0.002	0.17	0.46
Offal parts (%)								
Blood	4.5^{a}	4.2^{a}	4.1^{a}	3.4^{b}	0.13	0.001	0.24	0.34
Head	4.9^{ab}	5.0^{ab}	4.7^{b}	4.3^{bc}	0.10	0.001	0.19	0.78
Feet	2.2^{ab}	2.2^{ab}	2.1^{b}	1.7^{bc}	0.06	0.001	0.07	0.69
Skin	10.1	10.2	9.3	10.8	0.23	0.520	0.14	0.10
Liver	1.7^{ab}	1.6^{bc}	1.5^{cd}	1.2^{e}	0.05	0.001	0.59	0.53
Lung	1.6^{a}	1.3^{b}	1.3^{b}	1.1^{c}	0.05	0.001	0.78	0.08
Heart	0.35^{b}	0.45^{a}	0.40^{ab}	0.40^{ab}	0.01	0.350	0.05	0.06
Spleen	0.28^{a}	0.28^{a}	0.18^{b}	0.10^{b}	0.01	0.001	0.06	0.05
Kidney	0.23	0.28	0.25	0.20	0.01	0.400	0.07	0.65
Internal fat[4]	0.80^{b}	0.85^{b}	1.00^{b}	1.70^{a}	0.10	0.001	0.01	0.35
Side carcass cuts (kg)								
Neck	0.73	0.73	0.84	10.4	0.36	0.001	0.11	0.75
Shoulder	1.83	1.88	2.26	2.49	0.09	0.001	0.03	0.92
Brisket-flank	1.85	1.88	2.41	2.82	0.12	0.001	0.47	0.39
Rack-loin	1.66	1.78	20.1	2.34	0.08	0.002	0.39	0.99
Leg	2.94	3.18	3.78	4.29	0.16	0.001	0.50	0.61
Tail fat	1.50^{cd}	1.90^{c}	2.35^{bc}	3.23^{a}	0.19	0.001	0.25	0.66
Side carcass cuts (%)								
Neck	6.9	6.4	6.2	6.4	0.12	0.130	0.20	0.99
Shoulder	17.4	16.5	16.6	15.3	0.36	0.090	0.86	0.45
Brisket-flank	17.6	16.4	17.8	17.3	0.30	0.870	0.53	0.11
Rack-loin	15.8	15.7	14.8	14.4	0.35	0.140	0.87	0.71
Leg	27.8	28.0	27.9	26.3	0.60	0.460	0.52	0.84
Tail fat	14.2^{cd}	16.6^{abc}	17.3^{abc}	19.8^{ab}	0.86	0.030	0.97	0.62

[1] 56 d, 84 d, 112 d, and 140 d refer to date of experiment that lambs slaughtered.
[2] L: linear; Q: quadratic and C: cubic.
[3] On the basis of cold carcass weight.
[4] Kidney-pelvic-gut fat.
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.

Although some offal parts, such as the head, skin, and viscera, can be influential for this trait, one of the main influential factors is the components of the digestive tract and their contents, which play an essential role. The volume of the rumen, which forms the central part of the ruminant's digestive tract, is influenced by the type of diet; therefore, diets containing more forage cause its development. In other words, forage, in addition to being bulky compared to concentrate, is due to the absorption of more water, and as a result, the weight of the contents of the digestive tract will be heavier (Papi *et al*. 2011).

However, in some reports, the dressing percentage of fattened lambs has not changed significantly with the increase in the length of the fattening period (Alemzadeh *et al*. 2007; Norollahi, 2007), but in some other reports, it has increased with the aging of the fattened lambs, which is probably related to the higher growth rate of tissues, such as muscle and fat, and the lower growth rate of other tissues that have already grown (Farid *et al*. 1979; Talebi, 2013). In heavy lambs, the dressing percentage most often ranges between 40% to 52% of body weight and increases with body weight and fatness (Schreurs and Kenyon, 2017).

Table 4 Effects of slaughter age on fatty acid composition of longissimus dorsi muscle of Afshari male lambs

Fatty acids (g/100 g muscle)	Experimental period[1]				SEM	Contrasts[2]		
	day 56	day 84	day 112	day 140		L	Q	C
Caproic, C6:0	0.00	0.01	0.02	0.03	0.005	0.07	0.87	0.94
Caprilic, C8:0	0.11	0.09	0.07	0.08	0.010	0.23	0.41	0.71
Caprinic, C10:0	0.45	0.36	0.28	0.35	0.034	0.24	0.29	0.61
Lauric, C12:0	0.39^{a}	0.35^{a}	0.32^{a}	0.18^{b}	0.027	0.01	0.12	0.46
Myristic, C14:0	5.09^{a}	4.90^{a}	4.70^{a}	3.30^{b}	0.225	0.01	0.01	0.16
Myristoleic, C14:1	30.31^{ab}	28.73^{bc}	27.15^{cd}	25.61^{de}	0.572	0.01	0.97	0.98
Palmitic, C16:0	13.96^{a}	14.36^{a}	14.77^{a}	11.33^{b}	0.448	0.01	0.01	0.09
Palmitoleic, C16:1	0.31^{a}	0.22^{abc}	0.13^{c}	0.24^{abc}	0.028	0.15	0.07	0.37
Stearic, C18:0	0.32	0.32	0.32	0.27	0.015	0.23	0.40	0.77
Oleic, C18:1 n-9	2.42	2.54	2.70	2.60	0.051	0.17	0.36	0.67
Linoleic, C18:2 n-6	39.97^{b}	40.70^{b}	41.43^{b}	47.60^{a}	0.937	0.01	0.01	0.04
C18:1t	3.21^{bc}	3.71^{bc}	4.20^{ab}	4.30^{a}	0.167	0.01	0.44	0.73
Arachidic, C20:0	3.61	3.76	3.88	4.05	0.116	0.25	0.94	0.96
Total saturated fatty acids (SFA)	50.61^{a}	49.02^{b}	47.73^{c}	41.10^{d}	1.105	0.01	0.02	0.05
Total unsaturated fatty acids (UFA)	49.54^{d}	51.03^{c}	52.51^{b}	58.83^{a}	1.080	0.01	0.01	0.02
UFA:SFA	0.98^{d}	1.04^{c}	1.11^{b}	1.43^{a}	0.053	0.01	0.01	0.02
Fatty acids (g/100 g fat)								
Caproic, C6:0	0.10	0.13	0.17	0.08	0.28	0.93	0.36	0.67
Caprilic, C8:0	0.31^{bc}	0.41^{ab}	0.51^{a}	0.11^{d}	0.50	0.07	0.01	0.07
Caprinic, C10:0	0.37	0.47	0.58	0.43	0.030	0.17	0.11	0.21
Lauric, C12:0	0.68^{b}	0.82^{ab}	0.96^{a}	0.63^{b}	0.041	0.94	0.01	0.02
Myristic, C14:0	4.79^{d}	5.10^{bc}	5.41^{a}	5.26^{ab}	0.077	0.01	0.02	0.22
Myristoleic, C14:1	26.72^{b}	26.88^{b}	27.03^{b}	28.80^{a}	0.299	0..01	0.07	0.37
Palmitic, C16:0	13.47	13.35	13.24	15.41	0.548	0.29	0.34	0.66
Palmitoleic, C16:1	0.68^{bc}	0.98^{ab}	1.28^{a}	0.46^{cd}	0.101	0.52	0.01	0.04
Stearic, C18:0	0.68^{bc}	0.94^{ab}	1.20^{a}	0.46^{cd}	0.091	0.32	0.01	0.03
Oleic, C18:1 n-9	2.09^{ab}	3.01^{a}	3.21^{a}	2.54^{bc}	0.094	0.16	0.02	0.20
Linoleic, C18:2 n-6	37.80	37.30	36.83	37.26	0.325	0.52	0.53	0.78
C18:1t	7.31	6.40	5.49	5.31	0.430	0.10	0.68	0.85
Arachidic, C20:0	4.13^{a}	4.11^{a}	4.09^{a}	3.22^{b}	0.137	0.01	0.04	0.30
Total saturated fatty acids (SFA)	47.11^{bc}	48.13^{ab}	49.15^{ab}	51.17^{a}	0.676	0.04	0.68	0.85
Total unsaturated fatty acids (UFA)	52.83^{a}	51.82^{ab}	50.81^{ab}	48.78^{bc}	0.676	0.04	0.68	0.85
UFA:SFA	1.12^{a}	1.08^{ab}	1.03^{ab}	0.96^{bc}	0.027	0.04	0.76	0.92

[1] 56 d, 84 d, 112 d, and 140 d refer to date of experiment that lambs slaughtered.
[2] L: linear; Q: quadratic and C: cubic.
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.

These findings were consistent with the results of many reports published by other researchers (Mousavi *et al*. 2011; Talebi, 2013; Mashele *et al*. 2017; Mousavi *et al*. 2019).

As expected, hot and cold carcass values increased with increasing slaughter weight. According to Santos *et al*. (2015), which reported that hot carcass weight increased with enhancing live weight, the results of the present study for hot and cold carcass weight were not far from expectation.

There are some reports on increasing fat percentage of body weight by maturing of lamb (Perez *et al*. 2002; Hopkins *et al*. 2007). The commercial value of carcasses is determined by the fat and muscle content (Beriain *et al*. 2000), and the most critical factor in carcass conformation is age. The carcass becomes thicker and more compact as the animal ages (Prache *et al*. 2022).

Therefore, the proportion of muscle in the carcass decreases, and the proportion of fat increases by increasing body weight (Schreurs and Kenyon, 2017; Prache *et al*. 2022). Differences in maturity, age, or live weight at slaughter further contribute to differences in fatness (De Smet *et al*. 2004). Furthermore, tissue biochemical composition also changes, with muscle gaining lipid and losing water, with advancing maturity. The extent of the development of carcass fat as the sheep grows depends on potential adult body weight which varies with breed, sexual type and birth weight. In contrast our results, at a given body weight, there will be less fat in heavy or later-maturing breeds (Ye *et al*. 2020).

The tail fat is one of the tissues whose growth rate is slow in young animals, but with aging, especially in fattening male lambs, its growth rate increases (Farid *et al*. 1979).

Growth and fattening of meat animals is associated with increased fat deposition, first in subcutaneous and later in intramuscular fat (Vernon and Flint, 1988) and final tail fat. For a long time, one of the primary objectives of animal breeders has been to decrease carcass fatness (De Smet *et al*. 2004).

In agreement with our findings, other authors (Santos Silva *et al*. 2002b) reported that with the aging of fattening lambs, the fat content increased, and the lean meat content decreased. These authors also explained that carcass thickness increased when the slaughter weight of lambs increased (Santos Silva *et al*. 2002a; Diaz *et al*. 2003). Also, in other studies, by increasing the fattening period of Lori-Bakhtiari male lambs from 75 to 105 days (Talebi, 2013), and Turkey-Ghashghaii male lambs (Norollahi, 2007), the fat carcass content increased significantly. Therefore, the backfat thickness, which usually expands with the aging of fattening lambs (Purchas *et al*. 2002), could indicate the fat carcass content. Differences in fatness due to slaughter weight are significant, as they affect the abattoir classification of the carcasses (Miguel *et al*. 2003) and, thus, carcass price.

With increasing the weight of slaughter, side carcass cuts weight (neck, shoulder, brisket-flank, rack-loin, and leg) increased linearly (L=0.001), but side carcass percent were not affected. In heavy lambs, cuts can encompass several muscles, fat cover and intermuscular which are of particular importance. In these lambs, the carcass yield most often ranges between 40% and 52% of the body weight and increases with body weight and fatness (Schreurs and Kenyon, 2017). Cuts yield also depends on breed, increasing proportionally, at a given body weight in breeds that have higher fatness, higher muscling or muscle-to-bone ratio (Hegarty *et al*. 2006), or less non-carcass tissues. The sex effect is age-dependent. The percentages of cuts obtained in this study are similar to those found in light lambs in which the same jointing methodology was employed (Santos *et al*. 2007; Santos *et al*. 2008). This can be explained by the earlier development of the skeleton compared to other tissues (Warriss, 2000).

It should be acknowledged that the content of fatty acids varies in different tissues, such as intra- and intermuscular, abdominal (e.g., per renal, omental), and subcutaneous adipose tissue, as multiple authors have studied, for example, in beef cattle (Barber *et al*. 2000). In confirmation of our results, Cifuni *et al*. (2000) reported a higher percentage of total unsaturated fatty acid in the meat of lambs slaughtered at 45 days of age than those slaughtered at 90 days of age because of extensive hydrogenation performed by microorganisms in the rumen. Furthermore, a change in fatty acids profile has been reported to be associated with increasing levels of fatness (Casey *et al*. 1988). In agreement with the results of other authors (Beriain *et al*. 2000), the UFA content of LT fat in the present study increased with increasing live weight. This increase in the degree of unsaturation might be explained by the higher UFA content (Table 4), which is reflected in the increase in the ratio of UFA/SFA by aging lambs.

The increase in the quantity of UFA in the LT fat, with increased slaughter weight, may be attributable to acute hyperplasia in what may also be a late-developing depot (Jones, 1982). An increase in the proportion of unsaturated fatty acids in LT fat with increased slaughter weight (Table 4) might also be due to an increase in the activity of Δ9-desaturase in fattening lambs (Jackson and Winkler, 1970). Also, other authors note that the unsaturation of the fat depots increases with adiposity due to Δ9-desaturase enzyme activity, which is responsible for the synthesis of C18:1 from C18:0 (Diaz *et al*. 2003).

Because of the biohydrogenation of UFA in the rumen, beef, and lamb usually have a lower P/S ratio than the pig, indicating that the species is the principal source of variation in the fatty acid composition of meat (De Smet *et al*. 2004). The UFA/SFA ratio is usually used to assess the nutritional value of fat. Also, the presented low UFA/SFA is recognized as unfavorable because it may promote an increase in cholesterolemia (Santos Silva *et al*. 2002b).

Nurnberg *et al*. (1999) reported that growth from birth to slaughter at 24 months was accompanied by an increase in the intramuscular fat content and a continuous increase in the proportion of SFA during growth. The content of SFA increases faster with increasing fatness than does the content of PUFA, leading to a decrease in the relative proportion of PUFA and, consequently, the P/S ratio (De Smet *et al*. 2004). Differences in the fatty acid content of the main lipid fractions and their respective contributions to total lipids account for a considerable portion of the influence of fatness on the P/S ratio (De Smet *et al*. 2004).

CONCLUSION

With the diet fed to lambs in this study, as the slaughter weight of Afshari male lambs increased, DMI and FCR increased, but the trend of ADG was positive until the 56th day of the experiment, then decreased with a slight slope. Tail fat, backfat thickness and internal fat values increased when slaughter weight was gained, which could be attributed to the differential development of tissues in young lambs. With the increasing slaughter weight of lambs, the SFA in the LT fat increased, and the UFA decreased. However, in the LT muscle, the SFA decreased and UFA increased, which could be attributed to different conditional physiological conditions and digestive capabilities of lambs. Findings indicate the most appreciated slaughter

weight for Afshari male lambs is 50 to 55 kg.

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