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Effects of breed and fattening system on fatty acid and chemical composition of meat from male lambs

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Abstract

The purpose of this study was to examine the fatty acid and chemical composition of the *Longissimus dorsi* (LD) from male Tuj and Hemşin lambs reared in extensive, semi-intensive and intensive feeding systems. At the end of 90 days eight lambs from each breed and feeding system were slaughtered to determine chemical composition, and six lambs in each group were selected at random to assess fatty acid composition. Breed and feeding system interaction affected the quantities of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), and polyunsaturated fatty acids (PUFA), and the atherogenic (AI), thrombogenic (TI), and nutritive value (NVI) indices. In Hemşin the ratio of PUFA to SFA was higher in lambs fed in the extensive system than those produced in the semi-intensive and intensive systems, which were similar, whereas in Tuj this ratio decreased from the extensive to semi-intensive to intensive feeding systems. The ratio of omega n-6 to omega n-3 fatty acids was lower in the extensive and semi-intensive systems than it was in intensively fed Hemşin lambs, but increased with the intensity of feeding in Tuj lambs. Intramuscular fat content was higher in Hemşin lambs than in Tuj lambs and increased with the intensity of the feeding system. Conjugated linoleic acid content (CLA) was affected by feeding system in Hemşin lambs, but not in Tuj lambs. Because of their high PUFA/SFA ratio and low TI value, Tuj lambs reared in extensive feeding system were deemed to have the best performance.

Keywords: feeding intensity, health indicies, management, meat quality
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Introduction

To have adequate balanced nutrition and maintain a healthy life, 40 - 50% of human daily protein consumption should be of animal origin (Yılmaz & Yılmaz, 2012; Sevinç & Erçokun, 2020). In Turkey, the daily protein consumption per person is 108 g, and only 36% of this is of animal origin. Thus the Turkish people are far behind those in developed countries in consumption of animal protein (Doğan, 2019; TİGEM, 2019).

Sheep, a red meat source of protein, has 9.1% share of total red meat production in Turkey (TurkStat, 2021). Meat from lambs is preferred by Turkish consumers, and lamb production is the primary source of income for sheep breeders. Lamb meat is favoured by consumers because of its distinctive taste, smell, pinkish colour, short cooking time, and vitamin, mineral, and essential PUFA contents (Enser *et al.*, 1996; Wood *et al.*, 1999; Ponnampalam *et al.*, 2016; Junkuszew *et al.*, 2020). N-3 and n-6 fatty acids reduce the cholesterol level in the blood, especially triglycerides, and increase the high-density lipoprotein (HDL) level, thus helping to prevent cardiovascular disease (Feldman *et al.*, 1999; Öztürk, 2014; Çelebi *et al.*, 2017; Aksoy *et al.*, 2021). Omega n-3 and omega n-6 essential fatty acids help to prevent other diseases such as respiratory ailments, depression, obesity, rheumatoid arthritis, diabetes, and cancer (Simopoulos, 2002; Junkuszew *et al.*, 2020). On the other hand, saturated fatty acids hinder the clearance of low-density lipoprotein (LDL) in the blood and increase the risk of atherosclerosis (Öztürk, 2014). For example, myristic (C14:0) and palmitic (C16:0) acids increase blood LDL, whereas stearic acid (C18:0) decreases it (Williams,

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2000; Junkuszew *et al.*, 2020). For this reason, many researchers have stated that the n-6 to n-3 ratio in the diet should be from 5 : 1 to 3 : 1 and that of PUFA to SFA should be higher than 0.45 (Wood *et al.*, 1999; Ribeiro *et al.*, 2011; Aksoy *et al.*, 2021).

Conjugated linoleic acid, an omega-6 essential fatty acid, includes the geometric and positional isomers of linoleic acid (Williams, 2000; Eynard & Lopez, 2003; Kurban & Mehmetoğlu, 2006; Demirok & Kolsarıcı, 2010; Ulus & Gücükoğlu, 2017). It increases immune system function, has anti-carcinogenic effects, and inhibits the development of arteriosclerosis, thus having beneficial effects in terms of human health (Ulus & Gücükoğlu, 2017; den Hartigh, 2019). Additional effects of CLA include reducing body fat and insulin resistance, supporting the immune system, and increasing bone density and muscle mass (Kurban & Mehmetoğlu, 2006; Çelebi & Kaya, 2008; Lehnen *et al.*, 2015; Ulus & Gücükoğlu, 2017; Yılmaz & Şanlier, 2017). The CLA isomers 9-cis, 11-trans are formed by bacterial hydrogenation of dietary linoleic acid in ruminants (Williams, 2000; Kurban & Mehmetoğlu, 2006; Demirok & Kolsarıcı, 2010). Therefore, CLA is higher in meat from ruminant animals (Lehnen *et al.*, 2015). When fresh beef, veal, and lamb were evaluated, the highest CLA ratio was found in lamb meat (approximately 5.6 mg g^{-1} fat) (Kurban & Mehmetoğlu, 2006; Schmid *et al.*, 2006). The importance of lamb meat increases daily because of its high CLA and PUFA contents and because of consumer preferences for easy cooking, low loss, healthy meat. Therefore, researchers often focus on tissue fatty acid composition in lamb meats.

Tissue fatty acid composition in lambs is affected by factors such as feeding and production system (Cividini *et al.*, 2014; Ekiz *et al.*, 2019), slaughter weight (Yakan & Ünal, 2010; Aksoy & Ulutaş, 2016; Ekiz *et al.*, 2019), breed (Aksoy *et al.*, 2019; Budimir *et al.*, 2020), gender (Horcada-Ibáñez *et al.*, 2009; Vnučec *et al.*, 2016), and the muscle being analysed (Horcada-Ibáñez *et al.*, 2009; Aksoy *et al.*, 2019). Few studies describe the fatty acid composition of Hemşin and Tuj lambs in reared in different production systems. This study was carried out to determine the tissue fatty acid composition of the *LD* muscle from Hemşin and Tuj lambs produced in extensive, semi-intensive and intensive feeding systems.

Material and Methods

Approval was received by the Animal Experiments Local Ethics Committee of Kafkas University (Decision no: KAUHADYEK/2011-10). The study was conducted at the Application and Research Farm of the Faculty of Veterinary Medicine, Kafkas University for 90 days in the summer of 2012.

Male Hemşin lambs (n = 24), weaned at the age of three months, were purchased from Artvin province. Male Tuj lambs (n = 24), weaned at the age of three months, were obtained from Kafkas University Veterinary Faculty farm. Ten days after they had been apapted to pasture and concentrate mixture, the study randomly assigned eight lambs of each breed to the extensive, semi-intensive and intensive feeding systems. Medication against internal and external parasites was given lambs prior to the study. Lambs assigned to the extensive system were pasture fed for eight hours a day. Those in the semi-intensive sytem grazed on pasture and were given concentrate feed ad libitum. The lambs in the intensive system were given concentrate feed ad libitum and 270 g grass hay daily. The nutritive content of the pasture was determined periodically by mowing it to collect samples of the forage. Dry matter, organic matter, crude ash, crude protein, crude fat, crude cellulose, and nitrogen free extract contents were determined as prescribed by AOAC (1990). The nutrient profile of the pasture is presented in Table 1.

Table 1 Nutritional profile of pasture used for to impose differences in feeding system for lambs in the study of fatty acid profiles of their meat

Time	Dry matter	Organic matter	Ash	Crude protein	Crude fat	Crude cellulose	Nitrogen-free extract
First mowing	26.25	23.85	2.30	3.55	0.69	8.40	11.35
Second mowing	32.35	30.10	2.30	2.70	0.99	9.70	16.68
Third mowing	36.40	33.90	2.75	3.50	1.05	12.66	16.70

Average daily gain of Hemşin lambs in the extensive, semi-intensive and intensive systems was 121 g, 202 g and 213 g, respectively. Daily live weight gain of Tuj lambs in the extensive, semi-intensive and intensive systems was 118 g, 230 g and 221 g, respectively. The average concentrate feed consumptions of Hemşin and Tuj lambs per animal in the semi-intensive and intensive systems were 700 g and 1140 g. The concentrate feed consisted of 17.10% CP and 2910 kcal kg^{-1} metabolizable energy (NRC, 1985) and was prepared by a commercial company. Roughage was obtained from the Faculty of Veterinary Medicine farm.

After 90 days, eight randomly chosen lambs from each group were slaughtered to determine the chemical composition of the *LD*. In addition, six lambs in each group were randomly selected to assess the fatty acid content of the *LD*. After slaughter, the carcasses were kept at 4 °C for 24 hours. The *LD* muscle was then removed. The average slaughter weight of Hemşin and Tuj lambs in the extensive, semi-intensive and intensive systems were 32.45 and 31.00 kg, 43.17 and 41.67 kg, and 41.48 and 39.67 kg, respectively.

To determine fatty acid composition, 100 g *LD* muscle was removed and the fatty and connective tissues were detached with chloroform and methanol (2 : 1) and cold extraction (Folch *et al.,* 1957). After extraction, the triglyceride fatty acid was obtained in the lipid and converted into methyl ester (Anonymous, 1987). The fatty acid content of the *LD* muscle was analysed with a SHIMADZU - G 2010 Plus (Japan) gas chromatography device and a DB - 23 silica capillary column (60 m x 0.25 mm I.D. and 0.25 µm film thickness). Injector, column and detector heats were 230, 190 and 240 °C, respectively. Split ratio was 60 to 1. Carrier gas was helium at 0.5 mL/min ratio. Supelco 37 FAME mixture (C4-C24) and CLA 9t,11t, CLA 9c,11t and CLA 10t,12c (Sigma Aldrich) were used as external standards to identify the fatty acid. CLA 9t, 11t was not detected in all samples. Therefore total CLA was reported herein as the sum of CLA 9c,11t and CLA 10t,12c. The results were expressed as weight percentage (g per 100 g total fatty acid). The AI, TI, and NVI were calculated according to Garaffo *et al.* (2011) and Yakan and Ünal (2010).

The *LD* muscle samples were ground and then homogenized to determine the chemical composition. The DM, CP, and ash contents of the samples were measured according to the AOAC (1990). The intramuscular fat (IMF) content was assessed using the method of Okeudo and Moss (2007).

The data were analysed using the general linear model procedure of SPSS release 12 (SPSS Inc., Chicago, Illinios, USA). The model included the effects of breed, feeding system and two-factor interaction. Duncan's test was used to detect the differences between mean values. Effects were considered significant at the 0.05 level of probability.

Results and Discussion

Table 2 presents the means for the two-factor interaction of breed and feeding system for individual fatty acids. This was significant for eight of the 18 individual fatty acids. Least squares means for the main effects could be calculated by averaging the appropriate means reported in the table. On average, the concentration of palmitic acid (C16:0) increased with the intensity of the feeding system and was higher in Hemşin than Tuj lambs. In Hemşin lambs the concentration of stearic acid (C18:0) was similar when they were raised in the extensive and semi-intensive feeding systems, but increased under intensive management. In contrast, the Tuj lambs exhibited similar quantities of stearic acid in the extensive and intensive systems, but this was reduced under semi-intensive management. In Hemşin lambs the concentrations of oleic acid (C18:1) were similar when they were raised under semi-intensive and intensive systems, but reduced for those in the extensive system. In contrast, the quantities of C18:1 in the Tuj increased with the intensity of the feeding system.

Table 3 shows the effect of the breed by feeding system interaction on various indicies of the individual fatty acids. The AI indicates the relationship between SFAs that favour the adhesion of lipids to cells in the immune and circulatory systems to the MUFA and n-3 and n-6 PUFA, which inhibit aggregation of plaque and prevent the coronary diseases. In this study, the AI of the Tuj lambs was little affected by the intensity of the feeding system, whereas the Hemşin lambs showed increased AI as the intensity of the feeding system rose from extensive to semi-intensive to intensive. The TI is somewhat similar to the AI and indicates the tendency to form clots in blood vessels (Ulbricht & Southgate 1991; Vacca *et al.*, 2008). The TI increased with the intensity of the feeding system in both breeds, but the increase was larger and its levels were generally higher in Hemşin lambs than in Tuj lambs. The NVI refelcts the ratio of C18 fatty acids to C16:0 SFA and as such may indicate differences in the partioning of energy from these major dietary sources of fat. The NVI of fat from the *LD* of Hemşin lambs was higher in the extensive system than in the semi-intensive and intensive systems, which were similar to each other. In contrast, the Tuj lambs had higher NVI under extensive and intensive management and lower when reared in the semi-intensive system.

Table 2 Significance levels for the effect of breed, feeding system and their interaction on fatty acid composition (wt, %) of *Longissimus dorsi* muscle from Hemşin and Tuj lambs fed in extensive, semi-intensive and intensive feeding systems

Fatty acids	Treatments						SE[1]	*P*-values		
	H x EX	H x SI	H x IN	T x EX	T x SI	T x IN		Breed	System	Interaction
C14:0	1.95	2.55	2.20	2.48	2.70	2.51	0.147	0.005	0.014	0.378
C15:0	0.43	0.31	0.24	0.42	0.31	0.32	0.032	0.315	0.000	0.274
C16:0	21.05	23.83	23.97	20.52	22.80	20.96	0.250	0.000	0.000	0.471
C17:0	1.24	1.03	1.24	1.17	0.97	1.02	0.049	0.005	0.001	0.169
C18:0	20.17	19.99	21.68	16.47	15.48	16.88	0.219	0.000	0.000	0.012
C20:0	0.14	0.13	0.10	0.12	0.12	0.10	0.013	0.265	0.065	0.571
C22:0	1.31	0.42	0.28	1.57	0.64	0.41	0.103	0.012	0.000	0.768
C14:1	0.20	0.13	0.07	0.16	0.11	0.12	0.017	0.878	0.000	0.025
C15:1	0.13	0.13	0.05	0.12	0.10	0.13	0.017	0.250	0.080	0.010
C16:1	1.63	2.07	1.29	1.95	2.19	1.97	0.077	0.000	0.000	0.002
C17:1	0.50	0.44	0.50	0.59	0.51	0.56	0.029	0.013	0.119	0.887
C18:1	35.05	39.55	39.14	33.61	36.99	39.87	0.251	0.000	0.000	0.000
C20:1	0.23	0.17	0.13	0.14	0.14	0.13	0.021	0.003	0.004	0.030
C18:2 n-6	8.47	4.74	5.59	11.17	10.43	8.47	0.162	0.000	0.000	0.000
C18:3 n-3	2.55	1.22	0.66	3.00	1.56	0.71	0.115	0.003	0.000	0.153
C20:2 n-6	0.31	0.19	0.25	0.64	0.44	0.35	0.064	0.000	0.011	0.146
C20:3 n-3	0.28	0.17	0.19	0.39	0.29	0.23	0.042	0.006	0.008	0.536
C20:4 n-6	3.17	1.33	1.70	4.66	3.46	2.57	0.150	0.000	0.000	0.000

T: Tuj; H: Hemşin; EX: extensive; SI: semi -intensive; IN: intensive
[1]If SE are required for the breed average, this value can be divided by 1.73. Likewise if SE are required for the feeding system average, this value can be divided by 1.4

Table 3 Significance levels for the effect of breed, feeding system and their interaction on fatty acid composition (wt, %) of *Longissimus dorsi* muscle from Hemşin and Tuj lambs fed in extensive, semi-intensive and intensive feeding systems

Fatty acid indices	Treatments						SE[1]	P-values		
	H x EX	H x SI	H x IN	T x EX	T x SI	T x IN		Breed	System	Interaction
Saturated fatty acids (SFA)	46.28	48.27	49.72	42.74	43.03	44.20	0.317	0.000	0.000	0.004
Monounsaturated fatty acids	37.72	42.49	41.17	36.57	40.04	42.77	0.272	0.003	0.000	0.000
Conjugated linoleic acid	1.23	1.61	0.73	0.83	0.75	0.71	0.090	0.000	0.000	0.000
Polyunsaturated fatty acids (PUFA)	16.00	9.24	9.12	20.69	16.93	13.04	0.307	0.000	0.000	0.000
PUFA/SFA	0.35	0.19	0.18	0.48	0.39	0.30	0.008	0.000	0.000	0.000
Omega n-3 fatty acids	2.83	1.38	0.85	3.39	1.85	0.93	0.124	0.000	0.000	0.110
Omega n-6 fatty acids	11.95	6.25	7.54	16.47	14.32	11.39	0.254	0.000	0.000	0.000
n-6/n-3	4.26	4.53	9.11	4.94	7.83	12.81	0.658	0.000	0.000	0.036
Atherogenic index	0.52	0.58	0.61	0.46	0.46	0.48	0.013	0.000	0.000	0.022
Thrombogenic index	0.85	0.96	1.03	0.74	0.80	0.85	0.015	0.000	0.000	0.044
Nutritive value index	2.63	2.50	2.54	2.44	2.30	2.47	0.028	0.000	0.000	0.010

T: Tuj; H: Hemşin; EX: extensive; SI: eemi-intensive; IN: intensive
[1] If SE are required for the breed average, this value can be divided by 1.73. Likewise if SE are required for the feeding system average, this value can be divided by 1

Table 4 shows the results for chemical composition of LD. The interaction of breed and feeding system was not significant, excpet for the CP content of the LD. For the Tuj lambs, CP content of their LD muscle was lowest when they were reared in the extensive system and higher in the semi-intensive and intensive systems which were similar. The CP content of the LD from the Hemşin lambs was not affected by the feeding system. Breed had signifcant effects on IMF and moisture (or conversely DM) content of the LD with Hemşin lambs having a drier muscle with more IMF than Tuj lambs. The feeding system also affected IMF and the moisture content of the LD with both IMF and dry matter content increasing as the feeding system was intensified.

Table 4 Chemical composition of *Longissimus dorsi* muscle of Hemşin and Tuj lambs fed in extensive, semi-intensive and intensive feeding systems

Traits	N	IMF, %	A, %	DM, %	M, %	CP, %
Breed *P*-values		0.001	0.696	0.018	0.019	0.641
Tuj	24	1.00 ± 0.10	1.10 ± 0.01	22.71 ± 0.19	77.24 ± 0.19	20.61 ± 0.17
Hemşin	24	1.42 ± 0.10	1.10 ± 0.01	23.22 ± 0.14	76.73 ± 0.14	20.70 ± 0.13
Feeding system *P*-values		0.001	0.191	0.006	0.006	0.196
Extensive	16	0.99 ± 0.11^{b}	1.11 ± 0.01	22.51 ± 0.24^{b}	77.43 ± 0.23^{a}	20.42 ± 0.23
Semi-intensive	16	1.07 ± 0.13^{b}	1.09 ± 0.01	23.00 ± 0.21^{ab}	76.95 ± 0.20^{ab}	20.84 ± 0.18
Intensive	16	1.57 ± 0.12^{a}	1.09 ± 0.01	23.38 ± 0.14^{a}	76.58 ± 0.14^{b}	20.71 ± 0.13
Interaction of breed and feeding system *P*-values		0.138	0.458	0.075	0.081	0.008
Tuj: extensive	8	0.92 ± 0.16	1.10 ± 0.01	21.94 ± 0.35	77.99 ± 0.35	19.92 ± 0.35
Tuj: semi-intensive	8	0.70 ± 0.11	1.09 ± 0.01	22.77 ± 0.21	77.18 ± 0.19	20.98 ± 0.21
Tuj: intensive	8	1.38 ± 0.17	1.10 ± 0.01	23.40 ± 0.19	76.55 ± 0.19	20.92 ± 0.18
Hemşin: extensive	8	1.06 ± 0.17	1.12 ± 0.01	23.08 ± 0.14	76.88 ± 0.14	20.91 ± 0.16
Hemşin: semi-intensve	8	1.44 ± 0.13	1.10 ± 0.01	23.23 ± 0.35	76.73 ± 0.35	20.69 ± 0.30
Hemşin: intensive	8	1.76 ± 0.15	1.09 ± 0.01	23.35 ± 0.21	76.60 ± 0.21	20.50 ± 0.15

$^{a,b:}$ Feeding system comparisons are indicated by superscripts; means with a common superscript were similar (*P* >0.05)
IMF: intramuscular fat, A: ash, DM: dry matter, M: moisture, CP: crude protein

The current study revealed that the fatty acid composition of the *LD* muscle was generally affected by the interaction of breed and feeding system. More than 80% of total fatty acid content of the muscle was composed of C14:0, C16:0, C18:0, and C18:1 which was similar to the results of Karaca (2010). Çelik and Yılmaz (2010) found that the effect of breed (Awasi and Turkish Merino x Awasi F_1) on fatty acid composition was not significant. However, Demirel *et al.* (2006) found that the difference between the Sakız and Kıvırcık breeds was significant. The SFA values of Hemşin and Tuj lambs in this study were higher than those reported by Çelik and Yılmaz, (2010). The SFA value of Hemşin breed in this study was parallel with that reported by Aksoy and Ulutaş (2016) for the Karayaka breed in a serial slaughter experiment. However, SFA value of Tuj breed in the present study was lower than in the Karayaka (Aksoy & Ulutaş, 2016). Findings in the present study for the SFA and IMF contents were higher in the Hemşin lambs compared those of the Tuj breed. This may be because the Tuj lambs have fat accumulations localized around the femur and tail, whereas Hemşin lambs have a long tail with a small amount of fat at the tailhead (Uzun *et al*., 2006)

In the present study, the highest SFA content was observed lambs that were fed in the intensive system. Furthermore, the SFA values identified in all of three feeding system were higher than those presented by Önenç *et al.* (2015) for Sakiz lambs reared under traditional and intensive systems. However, the SFA contents were tem were lower than those found by Díaz *et al.* (2002) for Talaverana reared in pasture or intensive groups, and those of Yaralı & Karaca (2013) for Karya in all three feeding systems. The SFA values for lambs fed in the intensive system were similar to the results of Güler *et al.* (2011) for Akkaraman fed with concentrate. However, the SFA value of extensive was lower than reported by Güler *et al.* (2011) for pasture-reared mbs.

The MUFA values in this study were lower than those observed by Önenç *et al.* (2015) for pasture-fed Sakız lambs fed concentrate. The MUFA values of extensive and intensive system groups were higher than those determined by Díaz *et al.* (2002) for Talaverana reared in pasture and and those in an intensively managed group, but parallel with the results of Güler *et al.* (2011) for Akkaraman when managed similarly. The C16:1, C17:1, C21:1 and MUFA values identified for Hemşin and Tuj in the present study were lower than those reported by Yaralı & Karaca (2013) and Karabacak *et al.* (2014). On the other hand, C16:1 and C21:1 values of Hemşin and Tuj breeds were higher than the values determined by Karabacak (2015) for Akkaraman sheep.

In contrast to MUFA, lambs in the extensive system had the highest PUFA value. In the present study, the carboxylic acid (C18:3) content of the lambs in extensive group was higher than in semi-intensive and IN. Díaz *et al.* (2005) found that C18:3 values in pasture-fed lambs in Uruguay were the highest (3.37%). Similarly, C18:3 content was moderate in German and English meat lambs fed with pasture and abundant feed. Yousefi *et al.* (2012) reported that the fat-tailed Chall lambs had higher PUFA values than Zel lambs. The PUFA values in this study were higher than those reported for Malya (Karabacak *et al.*, 2013), Dağlıç (Karabacak *et al.*, 2014), Akkaraman (Karabacak, 2015), Bafra (Yakan & Ünal, 2010), and Karacabey Merino (Geçgel *et al.*, 2015) breeds. The PUFA contents observed in lambs from the extensive system in this study were lower than those reported by Cividini *et al.* (2014) for the Jezersko-Solcava breed reared on pasture, but higher than they reported for lambs in the intensive system.

In this study, the lambs fed in the extensive and semi-intensive systems had higher CLA content than those lambs that were reared intensively and the CLA contents of Hemşin were higher than those of Tuj. Nuernberg *et al.* (2008) reported that the CLA content of pasture-fed lambs was higher than those fed intensively. Díaz *et al.* (2005) found that English lambs had a higher CLA value (1.05%) than was observed for either breed of lambs in the present study, regardless of the feeding system under which they were managed.

In recent years, red meats have been criticized by the consumers because of possible risk to cardiovascular health from their consumption (Wood *et al.*, 1999; Nuernberg *et al.*, 2008; Aksoy & Ulutaş, 2016). Among all the fatty acids, n-3 fatty acids reduce LDL in the blood and thus decrease the risk of atherosclerosis. Following the findings of Okeudo and Moss (2007) and Vacca *et al.* (2008), the Turkish Department Health (1994) recommended that the PUFA/SFA ratio should be greater than 0.45 and that of n-6 to n-3 fatty acid should be less than 4 in human diets. The PUFA to SFA ratios of the Hemşin and Tuj breeds in this study were higher than those reported by Yakan and Ünal (2010) for Bafra sheep and by Aksoy and Ulutaş (2016) for Karayaka when slaughtered at 30, 35, and 40 kg. Additionally, the PUFA/SFA content of IN in this study was higher than that reported by Geçgel *et al.* (2015) for Karacabey Merino and by Yaralı and Karaca (2013) for Karya reared under intensive systems. Similar to the present results, Santos-Silva *et al.* (2002) reported the n-6/n-3 relationship in lambs on an extensive system was lower than those in semi-intensive and intensive systems. The n-6 to n-3 ratio in this study for lambs reared in the extensive system was similar to that reported by Yaralı and Karaca (2013) for Karya lambs reared under extensive and semi-intensive management, and higher than was reported by Güler *et al.* (2011) for pasture-fed Akkaraman sheep. The n-6/n-3 ratio of lambs from this study in the intensive group was higher than that reported by Yaralı and Karaca (2013) for Karya and lower than that reported by Güler *et al.* (2011) for Akkaraman lambs reared similarly.

The AI values observed in this study for the two breeds in the three systems were lower than those reported by Salvatori *et al.* (2004) for crossbred lambs reared extensively and slaughtered at 64 days old, by Oriani *et al.* (2005) for lambs slaughtered at various ages, and by Vacca *et al.* (2008) for various breeds. These differences may be alternative manifestations of the interaction of breed and feeding system observed in the current study. The TI value of lambs in the intensive system of this study was lower than was reported by Yakan and Ünal (2010) for Bafra slaughtered at 30 - 35 kg and higher than those slaughtered at 40 - 45 kg. In this study, the highest SFA, AI, and TI values were observed for intensively fed lambs in both breeds, presumably because of the increase in IMF with the consumption of more concentrate feed.

The IMF contents of the Hemşin and Tuj lambs were lower than those of Esenbuğa *et al.* (2009) for Awasi and Morkaraman lambs, despite their having similar ash and CP contents. Likewise, the moisture contents of the meat from Hemşin and Tuj lambs were similar to values reported by Caneque *et al.* (2004) for Manchego sheep and Esenbuğa *et al.* (2001) for Morkaraman, Tuj, and Awasi x Tuj crosses. Additionally, the IMF content of lambs in the extensive and intensive groups was lower than reported by Priolo *et al.* (2002) for Ile de France lambs reared similarly. The IMF and CP contents of the *LD* from lambs reared in the extensive system were lower than those reported by Steinshamn *et al.* (2010) for lambs grazing mountain pasture. However, the ash, DM, and CP contents of meat from lambs in the intensive group were parallel with those reported by Şen *et al.* (2011) for similarly reared Karayaka lambs. But, IMF content detected in the present study was lower than was reported by Şen *et al.* (2011) for Karayaka lambs. Although the IMF content of Hemşin lambs was higher than that of Tuj lambs, their meat was drier. In this study, breed and feeding system interaction did not affect the IMF, ash, and DM contents, but did influence the CP content.

Conclusion

Tuj lambs reared in the extensive system were deemed to have performed best because of their favourable PUFA/SFA ratio and low TI value. However, this assessment is tempered because these lambs had a lower CP content in the LD muscle.

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Authors' Contributions

MS, KÖ and MT designed the experiment. MS, YA, KÖ, HE, SAI, and MT collected the data. MS and YA performed the statistical analysis. MS, YA and KÖ wrote the paper. All authors reviewed and approved the manuscript.

Conflicts of Interest Declaration

The authors declare no conflict of interest.

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