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Full Length Research Paper

Effect of feeding regime on fatty acid composition and conjugated linoleic acid content of perirenal, omental and tail fat in Akkaraman lambs

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In this study, the effect of feeding regime on fatty acid composition including conjugated linoleic acid (CLA) of omental, perirenal and tail fat from Akkaraman lambs, the most widespread sheep breed in central Anatolia, was investigated. Forty-five suckling lambs, born in the same farm, were fed mainly maternal milk from birth to weaning and then the lambs were divided into three groups. One group (maternal milk-fed group) of the lambs was directly slaughtered after weaning. A second group (pasture group) was allowed to graze a natural pasture and slaughtered at three months after weaning. Third group (concentrate group) was fed concentrate *ad-libitum* together with 150 g/day alfalfa and slaughtered at three months after weaning. In all feeding regime, the predominant fatty acids were C 16:0 palmitic and C 18:0 stearic acid as saturated fatty acid (SFA), C 18:1ω9 oleic acid as monounsaturated fatty acid (MUFA) and C 18:2 ω6 linoleic acid as polyunsaturated fatty acid (PUFA). Omental, perirenal and tail fat of the pasture-fed lambs contained more total CLA, total ω3, ω3/ω6ratio compared with that of the concentrate-fed lambs. Moreover, omental, perirenal and tail fat of concentrate-fed lambs had higher ω6/ω3 ratio and this ratio was decreased by pasture feeding.

Key words: Akkaraman lambs, pasture, suckling, concentrate, fatty acid composition, conjugated linoleic acid.

INTRODUCTION

Conjugated linoleic acid (CLA) is a collective term for different positional and geometric isomers of octadecadienoic acid and naturally occurring fatty acid found in ruminant fats. Two of the isomers (*c*9,*t*11 and *t*10,*c*12) are known to possess biological activity (Pariza et al., 2001). The major CLA isomer, C 18:2 *c*9,*t*11, is produced in the rumen during the microbial biohydrogenation of dietary C 18:2 ω6 linoleic acid and in the tissues through Δ9 desaturation of C 18:1*t*11 (Griinari and Bauman, 1999). The *c*9,*t*11 CLA isomer appears to be the most biologically active isomer and accounts for more than 80% of CLA in ruminant products (Ha et al., 1990). There has been much interest in CLA because of its potential health benefits such as anti-carcinogenic, antiobesity, antidiabetogenic, antiathe-rogenic and antioxidative properties (Ha et al., 1990; Ip et al., 1994; Lee et al., 1994; Pariza et al., 1996; Parodi, 1997; Whigham et al., 2000; Kritchevsky, 2003; Park and Pariza, 2007).

Fatty acid composition of muscle and adipose tissues can be affected by many factors such as diet, breed, age of slaughter, fatness, body weight and sex (Kemp et al., 1981; Enser, 1991; Aharoni et al., 1995; Rule et al., 1995; Wood and Enser, 1997; Nürnberg et al., 1998; Mahgoub

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Abbreviations: CLA, Conjugated linoleic acid; **SFA,** saturated fatty acid; **MUFA,** monounsaturated fatty acid; **PUFA,** polyunsaturated fatty acid; **FID,** flame ionization detector; **FAME,** fatty acid methyl ester; **GC,** gas chromatography; **TFA,** *trans* fatty acid.

Table 1. Ingredients and chemical composition of the concentrate feed.

Ingredient	Percentage (%)
Corn	50
Bran	18.2
Soybean meal	4
Sodium chloride	1
Sunflower seed meal	21.6
Vegetable oil	2.15
Marble powder	2.8
Vitamin and mineral premix	0.25
Chemical composition	
Moisture	8.3
Ash	6.96
Crude protein	14.14
Starch	41.41
Crude fat	4.5
Crude fiber	9.81
Calculated metabolizable energy (kcal/kg)	2505

et al., 2002; Oriani et al., 2005; Demirel et al., 2006; Aurousseau et al., 2007a; Serra et al., 2009). The nutritional value of ω3 polyunsaturated fatty acids (PUFAs) in the human diet is well recognized and an increased consumption of these fatty acids has been recommended (Department of Health, 1994). Increasing the intake of ω3 PUFA appears to lower the risk of platelet aggregation and blood clotting, therefore decreasing the risk of thrombosis (Vanschoonbeek et al., 2003). Diet has been shown to be one of the main factors influencing fatty acid composition of fat in lambs (Wood et al., 2004). Grass-fed lambs display higher ω3 PUFA levels, while the proportion of ω6 PUFA increases in those fed with concentrate (Mitchell et al., 1991). Pasture feeding enhances the CLA in the tissue lipids of beef cattle (Dannenberger et al., 2005). Nutritional guidelines recommend a higher consumption of n-3 PUFA, suggesting a n-6/n-3 ratio at 4/1 or lower for the total diet (Department of Health, 1994). So, it is necessary to increase the ω3 unsaturated fatty acids and CLA with different feeding regimes for human health.

There is no information about the effect of feeding regime (maternal milk, pasture and concentrate) on CLA content, which is important for human health and fatty acid composition of omental, perirenal and tail fat from Akkaraman lambs. Akkaraman is the most widespread sheep breed in central Anatolia and accounts for 40 to 50% of sheep population in Turkey (Akman et al., 2001). Akkaraman sheep is one of the fat-tailed breeds and approximately 87% of the sheep population in Turkey is fat-tailed breeds (Anonymous, 2000).

The objective of the study was to characterize the effects of different feeding regime on fatty acid composition of omental, perirenal and tail fat, especially ω3 fatty acids and CLA, of Akkaraman lambs.

MATERIALS AND METHODS

Animals and feeding regime

Forty-five male Akkaraman suckling lambs, born in the same farm, were fed mainly maternal milk and a small amount of lamb starter during first three months from birth to weaning and then the suckling lambs were divided into three equal groups, each of 15 heads, with an average live weight of 25 kg. Determination of differences of fatty acid composition in lambs fed on three different feed was aimed. So, one group of the suckling lambs (only maternal milk-fed group) was directly slaughtered after weaning. After one week of adaptation period, another group of the suckling lambs was allowed to graze everyday on natural pasture (pasture group) from weaning to slaughter. These lambs were slaughtered at three months after weaning. A third group (concentrate group) was fed concentrate *ad libitum* together with 150 g/day alfalfa per lamb from weaning to slaughter. These lambs were slaughtered at three months after weaning. Concentrate-fed lambs were reared in "Selcuk University Agriculture Faculty, Department of Animal Science Prof. Dr. Orhan Düzgüneş Research and Application Farm". Ingredients and fatty acid composition of the concentrate feed are presented in Tables 1 and 2, respectively. Chemical composition of the feed sample was analyzed using the Weende-method.

Sampling

After slaughtering, carcasses were immediately transferred to cooler at 4°C. After 24 h conservation period, 10 g omental, perirenal and tail fat samples were collected from each carcass. Samples were vacuum packaged, frozen and stored at -27°C until analysis.

Fatty acid analyses

Total lipids of lambs were extracted with chloroform/methanol (2:1 v/v) according to Folch et al. (1957) method. Methyl esters were prepared by transmethylation, using KOH 2 mol/l in methanol and n-heptane, according to method 5509 of the ISO (1978).

The fatty acid methyl esters were analyzed on a HP Agilent 6890N model gas chromatograph (GC), equipped with a flame ionization detector (FID) and fitted with a HP-88 capillary column (100 m, 0.25 mm i.d. and 0.2 µm). Chromatographic conditions were performed according to Ledoux et al. (2005) method modified as follows: injector and detector temperatures were 250 and 280°C, respectively. The oven was programmed at 60°C initial temperature and 1 min initial time. Thereafter, the temperature increased at 20°C /min to 190°C held for 60 min then increased at 1°C/min to 220°C and held for 10 min at 220°C. Total run time was 107.5 min. The carrier gas was helium (1 ml/min).

Identification of fatty acids and *trans* isomers were carried out by comparing sample fatty acid methyl ester (FAME) peak relative

Table 2. Fatty acid composition of concentrate feed [a].

Fatty acid	Percentage (%)
C 14:0	0.08 ± 0.01 [b]
C 15:0	0.03 ± 0.00
C 16:0	12.33 ± 0.03
C 17:0	0.09 ± 0.02
C 18:0	3.18 ± 0.03
C 20:0	0.47 ± 0.08
∑ SFA [c]	16.18 ± 0.09
C 16:1ω-7	0.11 ± 0.02
C 17:1ω-8	0.07 ± 0.01
C 18:1ω-9	26.80 ± 0.07
C 20:1ω-9	0.35 ± 0.03
∑ MUFA [c]	27.32 ± 0.03
C 18:2ω-6	51.81 ± 0.15
C 18:3ω-6	0.27 ± 0.05
C 18:3ω-3	4.02 ± 0.01
C 20:5ω-3	0.24 ± 0.04
C 22:5ω-6	0.04 ± 0.01
C 22:5ω-3	0.14 ± 0.01
∑ PUFA [c]	56.51 ± 20.15
Σ ω-3	4.40 ± 0.05
Σ ω-6	52.12 ± 0.11
ω-3/ω-6	0.08 ± 0.00
ω-6/ω-3	11.85 ± 0.14

[a]Average of three lots analyzed; [b]values reported are mean ± SD. [c]SFA: Saturated fatty acid; MUFA: monounsaturated fatty acid; PUFA: polyunsaturated fatty acid.

retention times with those obtained from Alltech, Nu-Check Prep. Inc. USA and Accu standards. Linoleic acid conjugated methyl ester (mixture of *cis*- and *trans*-9,11- and -10,12-octadecadienoic acid methyl esters, catalog number O5632) was purchased from Sigma-Aldrich (St Louis, MO, USA). Results were expressed as FID response area relative percentages. Each reported result is the average value of three GC analyses. The results were presented as mean ± SD.

Statistical analysis

The results were submitted to analysis of variance (ANOVA), at 0.05 significance level, using SPSS 10.0 for Windows. The mean values were compared with Duncan test.

RESULTS AND DISCUSSION

Slaughter traits and total lipid levels in omental, perirenal and tail fat are presented in Tables 3 and 4, respectively. Fatty acid composition of omental, perirenal and tail fat from lambs of the three groups are presented in Tables 5, 6 and 7, respectively.

In all feeding regime, the predominant fatty acids in perirenal, omental and tail fat were C 16:0 palmitic acid and C 18:0 stearic acid as saturated fatty acid (SFA), C 18:1ω9 oleic acid as monounsaturated fatty acid (MUFA) and C 18:2ω6 linoleic acid as PUFA. These results are similar to those reported by Ünsal and Aktaş (2003), Ünsal and Yanlic (2005) and Yilmaz and Karakaya (2010) on the fatty acid composition of sheep tail fat and intestinal fat. Moharrey (2007) have also reported that, three major fatty acids in omental fat of fat-tailed Badghisian sheep were palmitic acid, stearic acid and oleic acid. Osorio et al. (2009) have also reported similar results for fatty acid composition of omental and perirenal fat of suckling lambs reared on ewe's milk.

Total SFA was 54.67, 48.95 and 63.75% of total fatty acids in omental fat, 55.48, 49.29 and 61.06% of total fatty acids in perirenal fat and 47.42, 38.82 and 47.49% of total fatty acids in tail fat from maternal milk, concentrate and pasture-fed lambs, respectively. Arana et al. (2006) have also reported similar values of total SFA (49.68%) for perirenal depots of lambs fed a concentrate diet. In the present study, total SFA in maternal milk, concentrate and pasture-fed lamb's omental and perirenal fat was significantly affected by feeding regime ($P < 0.05$). Additionally, total SFA in tail fat from concentrate-fed lambs was significantly lower than those of maternal milk and pasture-fed lambs ($P < 0.05$). Palmitic acid, stearic acid and myristic acid (C 14:0) were the major SFA from maternal milk, pasture and concentrate-fed lambs in omental, perirenal and tail fat. These results agree with those reported by Ünsal and Aktaş (2003), Ünsal and Yanlic (2005) and Yilmaz and Karakaya (2010) for tail fat, Moharrey (2007) and Osorio et al. (2009) for omental fat and Arana et al. (2006) and Osorio et al. (2009) for perirenal fat who reported that palmitic acid, stearic acid and myristic acid were major SFA in sheep and lambs. In the present study, total SFA, palmitic acid, stearic acid, myristic acid and lauric acid (C 12:0) in omental, perirenal and tail fat of pasture-fed lambs were higher than those of concentrate-fed lambs. Nuernberg et al. (2008) have also reported that total SFA, palmitic acid, stearic acid, myristic acid and lauric acid in tail fat of male Skudde lambs fed pasture were higher than those of concentrate-fed lambs.

Total MUFA was 35.51, 34.16 and 30.40% of total fatty acids in omental fat, 35.27, 34.01 and 27.47% of total fatty acids in perirenal fat and 42.86, 45.34 and 42.43% of total fatty acids in tail fat from maternal milk, concentrate and pasture-fed lambs, respectively. In previous studies, total MUFA have been determined as 30.33% in perirenal fat of alpaca reared under a traditional unspecialized production system at the Andean region of Peru (Salva et al., 2009), 36.74% in omental fat deposit of suckling lambs reared on ewe's milk (Osorio et al., 2009), 42.16% in tail fat of Akkaraman sheep (Yilmaz and Karakaya, 2010) and 47.93% in tail fat of Akkaraman

Table 3. Slaughter traits in the three groups.

Slaughter trait	Maternal milk group (n=15) mean ± SE*	Concentrate group (n=15) mean ± SE*	Pasture group (n=15) mean ± SE*
Age at slaughter (days)	90	180	180
Live weight at slaughter (kg)	25.18 ± 0.75	46.08 ± 0.75	35.07 ± 0.55
Hot carcass weight (kg)	12.44 ± 0.49	24.05 ± 1.60	17.20 ± 0.94

*SE, Standard error of the mean.

Table 4. Total lipid levels in omental, perirenal and tail fat of Akkaraman lambs.

Group	Total lipid (%)		
	Omental fat, mean ± SD*	Perirenal fat, mean ± SD	Tail fat, mean ± SD
Maternal milk-fed group	66.1±1.19	67.1±1.23	76.8±0.53
Concentrate-fed group	76.3±0.5	72.2±0.87	78.2±0.7
Pasture-fed group	42.9±0.46	59.8±0.93	66.1±0.86

*SD, Standard deviation of the mean.

lambs fed with fresh alfalfa (Ciftci et al., 2010). In the present study, total MUFA in omental and perirenal fat of maternal milk-fed lambs was significantly higher than those of pasture-fed lambs ($P < 0.05$). Perirenal and omental fat from animals fed maternal milk and concentrate diets had significantly higher oleic acid than pasture-fed ($P < 0.05$). In oleic acid of tail fat, no statistical differences were observed between feeding regime ($P > 0.05$).

Total PUFA was 3.75, 4.74 and 2.20% of total fatty acids in omental fat, 3.81, 4.75 and 3.07% of total fatty acids in perirenal fat and 3.73, 4.98 and 3.14% of total fatty acids in tail fat from maternal milk, concentrate and pasture-fed lambs, respectively. Ciftci et al. (2010) have also reported higher values of PUFA (10.48%) for tail fat of lambs fed with fresh alfalfa compared with results of the present study. Total PUFA have been stated as 2.11% in tail fat of Akkaraman sheep (Yilmaz and Karakaya, 2010). Osorio et al. (2009) have also reported higher values of PUFA in omental (5.45%) and perirenal fat (5.75%) deposit of suckling lambs reared on ewe's milk compared with our values. Salva et al. (2009) have found that, total PUFA was 5.75% in perirenal fat of alpaca. In the present study, total PUFA in omental, perirenal and tail fat was significantly higher in concentrate-fed lambs than maternal milk and pasture-fed lambs ($P < 0.05$). The high value of linoleic acid (51.81% of total fatty acids; Table 2) in concentrate feed increased this fatty acid and total PUFA in omental, perirenal and tail fat of concentrate-fed lambs. On the other hand, Nuernberg et al. (2008) have determined that, total PUFA in tail fat of lambs fed on pasture was higher than those of concentrate-fed lambs. In the present study, linoleic acid was the most represented PUFA and was significantly higher in concentrate-fed lambs than maternal milk and pasture-fed lambs in omental, perirenal and tail fat ($P < 0.05$). These results agree with those reported by Nuernberg et al. (2008), who related that, linoleic acid was higher in tail fat of lambs fed concentrate compared with grass fed animals. Grazing lambs on pasture led to a significant increase of C 18:3ω3 α-linolenic acid in the perirenal and tail fat of Akkaraman lambs as they consumed grass which is rich in linolenic acid ($P < 0.05$).

The predominant CLA isomers of three CLA isomers in omental, perirenal and tail fat was C18:2 *c*9,*t*11. Total CLA was significantly higher in omental fat of maternal milk-fed lambs than those of concentrate and pasture-fed lambs ($P < 0.05$; Table 5). However, pasture feeding significantly enhanced total CLA in perirenal fat of Akkaraman lambs ($P < 0.05$; Tables 6). Aurousseau et al. (2007b) stated that, grazing have lowered ω6 PUFA and increased ω3 PUFA and C 18:2 *c*9*t*11 compared with concentrate feeding. Feeding grass-based diets increases the 18:2 *c*9,*t*11 content of ruminant fat (French et al., 2000). In the present study, C18:2 *c*9,*t*11 and total CLA in perirenal and tail fat of pasture-fed lambs was higher about two or three times than those of concentrate-fed lambs. CLA amounts in adipose tissues have been determined as 3 to 4 times higher in Akkaraman lambs fed with alfalfa than lambs fed with wheat straw (Ciftci et al., 2010).

Total *trans* fatty acid (TFA) was found as 5.11, 11.76 and 3.18% of total fatty acids in omental fat, 4.61, 11.57 and 7.41% of total fatty acids in perirenal fat and 4.87, 10.12 and 5.68% of total fatty acids in tail fat from maternal milk, concentrate and pasture-fed lambs, respectively. Major TFA was C 18:1 *t*11 *trans*-vaccenic acid in omental, perirenal and tail fat of maternal milk, concentrate and pasture-fed lambs. *Trans* vaccenic acid

Table 5. Fatty acid composition (%) of omental fat of lambs fed diets containing maternal milk, concentrate and pasture[x].

Fatty acid	Maternal milk group (n=15)	Concentrate group (n=15)	Pasture group (n=15)
C 10:0*	0.45 ± 0.08 [a, y]	0.22 ± 0.05 [b]	0.29 ± 0.08 [b]
C 11:0	0.03 ± 0.01 [a, z]	0.01 ± 0.00 [b]	0.01 ± 0.00 [b]
C 12:0	1.01 ± 0.26 [a]	0.15 ± 0.04 [c]	0.35 ± 0.19 [b]
C 13:0	0.09 ± 0.03 [a]	0.02 ± 0.01 [b]	0.04 ± 0.02 [b]
C 14:0	8.89 ± 1.30 [a]	3.15 ± 0.50 [c]	4.76 ± 1.19 [b]
C 15:0	0.88 ± 0.12 [a]	0.56 ± 0.10 [b]	0.90 ± 0.13 [a]
C 16:0	26.13 ± 1.52 [a]	21.58 ± 1.02 [c]	23.55 ± 1.35 [b]
C 17:0	1.45 ± 0.16 [b]	2.04 ± 0.44 [a]	1.71 ± 0.23 [b]
C 18:0	15.31 ± 2.46 [c]	20.92 ± 3.73 [b]	31.30 ± 3.05 [a]
C 19:0	0.32 ± 0.08 [a]	0.12 ± 0.02 [b]	0.12 ± 0.04 [b]
C 20:0	0.07 ± 0.02 [c]	0.11 ± 0.02 [b]	0.57 ± 0.06 [a]
C 21:0	0.02 ± 0.01 [b]	0.05 ± 0.02 [a]	0.04 ± 0.01 [a]
C 22:0	0.01 ± 0.01 [b]	0.02 ± 0.01 [b]	0.11 ± 0.04 [a]
Σ SFA[t]	54.67 ± 4.43 [b]	48.95 ± 3.35 [c]	63.75 ± 3.53 [a]
C 14:1ω-5	0.29 ± 0.07 [b]	0.20 ± 0.04 [c]	0.64 ± 0.12 [a]
C 15:1ω-5	0.21 ± 0.02 [b]	0.08 ± 0.03 [c]	0.46 ± 0.07 [a]
C 16:1ω-7	2.85 ± 0.51 [a]	1.27 ± 0.17 [c]	1.92 ± 0.12 [b]
C 17:1ω-8	0.73 ± 0.25 [a]	0.60 ± 0.18 [a]	0.37 ± 0.07 [b]
C 18:1ω-9	30.29 ± 3.39 [a]	30.49 ± 3.12 [a]	26.46 ± 3.58 [b]
C 18:1ω-7	1.09 ± 0.26 [a]	1.50 ± 0.62 [a]	0.52 ± 0.09 [b]
C 20:1ω-9	0.03 ± 0.02 [a]	0.01 ± 0.01 [b]	0.01 ± 0.00 [b]
C 22:1ω-9	0.01 ± 0.00 [a]	0.01 ± 0.01 [a]	0.01 ± 0.00 [a]
Σ MUFA[t]	35.51 ± 4.28 [a]	34.16 ± 3.34 [ab]	30.40 ± 3.45 [b]
C 18:2ω-6	2.88 ± 0.43 [b]	4.13 ± 0.68 [a]	1.64 ± 0.07 [c]
C 18:3ω-6	0.09 ± 0.02 [a]	0.02 ± 0.01 [b]	0.01 ± 0.00 [b]
C 18:3ω-3	0.26 ± 0.04 [a]	0.20 ± 0.03 [b]	0.24 ± 0.05 [a]
C 20:2ω-6	0.06 ± 0.01 [b]	0.07 ± 0.02 [a]	0.02 ± 0.00 [c]
C 20:3ω-6	0.04 ± 0.01 [a]	0.03 ± 0.01 [b]	0.02 ± 0.01 [c]
C 20:3ω-3	0.02 ± 0.01 [a]	0.02 ± 0.01 [a]	0.03 ± 0.02 [a]
C 20:4ω-6	0.14 ± 0.04 [a]	0.08 ± 0.02 [b]	0.06 ± 0.02 [b]
C 20:5ω-3	0.02 ± 0.01 [a]	0.02 ± 0.01 [a]	0.02 ± 0.01 [a]
C 22:2ω-6	0.02 ± 0.01 [a]	0.02 ± 0.01 [a]	0.01 ± 0.01 [a]
C 22:3ω-3	0.07 ± 0.06 [a]	0.05 ± 0.04 [a]	0.04 ± 0.03 [a]
C 22:4ω-6	0.05 ± 0.02 [a]	0.04 ± 0.02 [a]	0.01 ± 0.01 [b]
C 22:5ω-6	0.02 ± 0.01 [a]	0.02 ± 0.01 [a]	0.01 ± 0.01 [a]
C 22:5ω-3	0.09 ± 0.02 [a]	0.03 ± 0.02 [b]	0.08 ± 0.01 [a]
C 22:6ω-3	0.02 ± 0.01 [a]	0.02 ± 0.01 [a]	0.01 ± 0.00 [a]
Σ PUFA[t]	3.75 ± 0.48 [b]	4.74 ± 0.71 [a]	2.20 ± 0.12 [c]
C 18:2 *c*9, *t*11	0.94 ± 0.24 [a]	0.34 ± 0.07 [b]	0.45 ± 0.07 [b]
C 18:2 *t*10, *c*12	0.01 ± 0.00 [b]	0.04 ± 0.01 [a]	0.01 ± 0.00 [b]
C 18:2 *c*11, *t*13	0.01 ± 0.00 [b]	0.02 ± 0.02 [a]	0.01 ± 0.00 [b]
Σ CLA[t]	0.96 ± 0.24 [a]	0.40 ± 0.08 [b]	0.47 ± 0.07 [b]
C 14:1*t*9	0.25 ± 0.05 [b]	0.08 ± 0.05 [c]	0.40 ± 0.06 [a]
C 16:1*t*9	0.50 ± 0.05 [a]	0.16 ± 0.04 [b]	0.49 ± 0.05 [a]
C 18:1 *t*9	0.02 ± 0.01 [a]	0.01 ± 0.00 [b]	0.02 ± 0.01 [a]

Table 5. Continue.

C 18:1 *t*11	3.90 ± 1.00 [b]	11.36 ± 3.46 [a]	2.04 ± 0.22 [b]
C 18:2 *t*9, *t*12	0.27 ± 0.06 [a]	0.08 ± 0.04 [b]	0.12 ± 0.10 [b]
C 18:2 *t*9, *c12*	0.18 ± 0.08 [a]	0.07 ± 0.02 [b]	0.11 ± 0.04 [b]
Σ TFA[t]	5.11 ± 1.02 [b]	11.76 ± 3.50 [a]	3.18 ± 0.14 [b]
Σ ω-3	0.48 ± 0.11 [a]	0.33 ± 0.09 [b]	0.41 ± 0.09 [ab]
Σ ω-6	3.29 ± 0.45 [b]	4.40 ± 0.69 [a]	1.79 ± 0.06 [c]
ω-3/ω-6	0.14 ± 0.04 [b]	0.08 ± 0.02 [c]	0.23 ± 0.05 [a]
ω-6/ω-3	6.85 ± 1.63 [b]	13.33 ± 3.12 [a]	4.37 ± 1.11 [c]

[x]Average of three lots analyzed; [Y]values reported are mean ± SD; [z]abc values for each sample with different letters in the same fraction are significantly different at $p < 0.05$. [t]SFA: Saturated fatty acid; MUFA: monounsaturated fatty acid; PUFA: polyunsaturated fatty acid; TFA: *trans* fatty acid; CLA: conjugated linoleic acid.

Table 6. Fatty acid composition (%) of perirenal fat of lambs fed diets containing maternal milk, concentrate and pasture[x].

Fatty acid	Maternal milk group (n=15)	Concentrate group (n=15)	Pasture group (n=15)
C 10:0*	0.36 ± 0.08 [a, y]	0.21 ± 0.03 [b]	0.42 ± 0.26 [a]
C 11:0	0.02 ± 0.01 [a, z]	0.01 ± 0.01 [b]	0.01 ± 0.01 [b]
C 12:0	0.73 ± 0.16 [a]	0.12 ± 0.03 [b]	0.61 ± 0.40 [a]
C 13:0	0.06 ± 0.02 [a]	0.03 ± 0.02 [c]	0.04 ± 0.02 [b]
C 14:0	6.94 ± 1.18 [a]	2.87 ± 0.55 [b]	6.76 ± 3.62 [a]
C 15:0	0.65 ± 0.15 [b]	0.53 ± 0.30 [b]	0.94 ± 0.23 [a]
C 16:0	21.59 ± 2.04 [ab]	19.95 ± 1.97 [b]	22.80 ± 3.29 [a]
C 17:0	1.59 ± 0.15 [b]	2.00 ± 0.43 [a]	1.59 ± 0.13 [b]
C 18:0	23.18 ± 4.98 [a]	23.24 ± 4.53 [a]	27.05 ± 4.60 [a]
C 19:0	0.25 ± 0.11 [a]	0.11 ± 0.05 [b]	0.24 ± 0.06 [a]
C 20:0	0.07 ± 0.05 [c]	0.15 ± 0.03 [b]	0.48 ± 0.12 [a]
C 21:0	0.02 ± 0.01 [c]	0.05 ± 0.01 [a]	0.04 ± 0.02 [b]
C 22:0	0.01 ± 0.00 [b]	0.02 ± 0.01 [b]	0.10 ± 0.05 [a]
Σ SFA[t]	55.48 ± 3.56 [b]	49.29 ± 2.91 [c]	61.06 ± 3.32 [a]
C 14:1ω-5	0.20 ± 0.14 [b]	0.19 ± 0.06 [b]	0.52 ± 0.11 [a]
C 15:1ω-5	0.18 ± 0.03 [b]	0.08 ± 0.04 [c]	0.29 ± 0.05 [a]
C 16:1ω-7	2.11 ± 0.79 [a]	1.19 ± 0.35 [b]	1.52 ± 0.18 [b]
C 17:1ω-8	0.60 ± 0.20 [a]	0.55 ± 0.27 [a]	0.33 ± 0.08 [b]
C 18:1ω-9	31.05 ± 2.50 [a]	30.44 ± 3.01 [a]	24.19 ± 1.21 [b]
C 18:1ω-7	1.09 ± 0.21 [b]	1.54 ± 0.46 [a]	0.60 ± 0.21 [c]
C 20:1ω-9	0.03 ± 0.01 [a]	0.01 ± 0.00 [b]	0.01 ± 0.00 [b]
C 22:1ω-9	0.01 ± 0.01 [a]	0.01 ± 0.00 [a]	0.01 ± 0.00 [a]
Σ MUFA[t]	35.27 ± 3.40 [a]	34.01 ± 3.23 [a]	27.47 ± 1.46 [b]
C 18:2ω-6	3.00 ± 0.43 [b]	4.21 ± 0.70 [a]	1.84 ± 0.31 [c]
C 18:3ω-6	0.14 ± 0.06 [a]	0.02 ± 0.01 [b]	0.02 ± 0.00 [b]
C 18:3ω-3	0.25 ± 0.05 [b]	0.19 ± 0.04 [b]	0.87 ± 0.25 [a]
C 20:2ω-6	0.06 ± 0.01 [b]	0.07 ± 0.02 [a]	0.06 ± 0.02 [b]
C 20:3ω-6	0.05 ± 0.02 [a]	0.03 ± 0.01 [b]	0.02 ± 0.00 [b]
C 20:3ω-3	0.02 ± 0.01 [b]	0.02 ± 0.01 [b]	0.04 ± 0.03 [a]
C 20:4ω-6	0.11 ± 0.05 [a]	0.06 ± 0.02 [b]	0.03 ± 0.01 [b]
C 20:5ω-3	0.02 ± 0.01 [a]	0.02 ± 0.01 [a]	0.02 ± 0.01 [a]

Table 6. Continue.

C 22:2ω-6	0.02 ± 0.01 [a]	0.02 ± 0.01 [a]	0.02 ± 0.01 [a]
C 22:3ω-3	0.04 ± 0.03 [a]	0.03 ± 0.02 [a]	0.04 ± 0.02 [a]
C 22:4ω-6	0.03 ± 0.01 [a]	0.03 ± 0.02 [a]	0.01 ± 0.01 [b]
C 22:5ω-6	0.01 ± 0.00 [a]	0.02 ± 0.01 [a]	0.02 ± 0.01 [a]
C 22:5ω-3	0.06 ± 0.02 [b]	0.02 ± 0.01 [c]	0.09 ± 0.02 [a]
C 22:6ω-3	0.02 ± 0.01 [a]	0.02 ± 0.01 [a]	0.02 ± 0.01 [a]
Σ PUFA[t]	3.81 ± 0.54 [b]	4.75 ± 0.70 [a]	3.07 ± 0.42 [c]

[x]Average of three lots analyzed; [y]values reported are mean ± SD; [z]abc values for each sample with different letters in the same fraction are significantly different at $p < 0.05$. [t]SFA: Saturated fatty acid; MUFA: monounsaturated fatty acid; PUFA: polyunsaturated fatty acid; TFA: trans fatty acid; CLA: conjugated linoleic acid.

Table 7. Fatty acid composition (%) of tail fat of lambs fed diets containing maternal milk, concentrate and pasture[x].

Fatty acid	Maternal milk group (n=15)	Concentrate group (n=15)	Pasture group (n=15)
C 10:0*	0.48 ± 0.07 [a, y]	0.24 ± 0.06 [b]	0.28 ± 0.11 [b]
C 11:0	0.04 ± 0.01 [ab, z]	0.05 ± 0.04 [a]	0.02± 0.01 [b]
C 12:0	0.76 ± 0.27 [a]	0.31 ± 0.16 [b]	0.36 ± 0.17 [b]
C 13:0	0.09 ± 0.03 [a]	0.09 ± 0.04 [a]	0.05 ± 0.03 [b]
C 14:0	7.38 ± 1.65 [a]	2.99 ± 0.70 [c]	5.18 ± 1.28 [b]
C 15:0	0.99 ± 0.17 [b]	1.52 ± 0.41 [a]	0.99 ± 0.17 [b]
C 16:0	24.85 ± 2.06 [a]	20.74 ± 2.55 [c]	22.98 ± 0.82 [b]
C 17:0	1.65 ± 0.33 [b]	2.99 ± 0.61 [a]	1.76 ± 0.22 [b]
C 18:0	10.66 ± 3.30 [b]	9.38 ± 1.99 [b]	15.13 ± 4.70 [a]
C 19:0	0.44 ± 0.09 [a]	0.34 ± 0.09 [b]	0.45 ± 0.09 [a]
C 20:0	0.07 ± 0.03 [b]	0.09 ± 0.02 [b]	0.25 ± 0.14 [a]
C 21:0	0.02 ± 0.01 [b]	0.05 ± 0.03 [a]	0.03 ± 0.01 [b]
C 22:0	0.01 ± 0.00 [b]	0.02 ± 0.01 [a]	0.02 ± 0.01[a]
Σ SFA[t]	47.42 ± 5.49 [a]	38.82 ± 3.63 [b]	47.49 ± 3.25 [a]
C 14:1ω-5	0.39 ± 0.07 [b]	0.42 ± 0.17 [b]	0.59 ± 0.17 [a]
C 15:1ω-5	0.22 ± 0.03 [b]	0.24 ± 0.12 [ab]	0.31 ± 0.04 [a]
C 16:1ω-7	3.73 ± 0.67 [a]	2.80 ± 0.70 [b]	3.10 ± 1.00 [b]
C 17:1ω-8	1.24 ± 0.35 [b]	2.30 ± 0.91 [a]	1.01 ± 0.39 [b]
C 18:1ω-9	35.81 ± 4.81 [a]	37.84 ± 4.71 [a]	36.66 ± 3.45 [a]
C 18:1ω-7	1.41 ± 0.35 [a]	1.68 ± 0.52 [a]	0.75 ± 0.23 [b]
C 20:1ω-9	0.06 ± 0.02 [a]	0.05 ± 0.03 [a]	0.01 ± 0.00 [b]
C 22:1ω-9	0.01 ± 0.00 [a]	0.02 ± 0.01 [a]	0.01 ± 0.00 [a]
Σ MUFA[t]	42.86 ± 5.93 [a]	45.34 ± 6.19 [a]	42.43 ± 4.88 [a]
C 18:2ω-6	2.90 ± 0.46 [b]	4.16 ± 0.76 [a]	1.86 ± 0.60 [c]
C 18:3ω-6	0.09 ± 0.03 [a]	0.03 ± 0.01 [b]	0.04 ± 0.01 [b]
C 18:3ω-3	0.27 ± 0.05 [b]	0.24 ± 0.05 [b]	0.75 ± 0.47 [a]
C 20:2ω-6	0.06 ± 0.01 [b]	0.09 ± 0.02 [a]	0.05 ± 0.02 [b]
C 20:3ω-6	0.04 ± 0.01 [a]	0.04 ± 0.02 [a]	0.02 ± 0.00 [b]
C 20:3ω-3	0.02 ± 0.01 [b]	0.03 ± 0.02 [a]	0.04 ± 0.02 [a]
C 20:4ω-6	0.13 ± 0.06 [a]	0.09 ± 0.04 [b]	0.08 ± 0.04 [b]
C 20:5ω-3	0.02 ± 0.01 [b]	0.03 ± 0.02 [a]	0.02 ± 0.01 [b]
C 22:2ω-6	0.02 ± 0.01 [b]	0.03 ± 0.02 [a]	0.02 ± 0.01 [b]
C 22:3ω-3	0.05 ± 0.04 [b]	0.09 ± 0.06 [ab]	0.12 ± 0.07 [a]
C 22:4ω-6	0.05 ± 0.03 [ab]	0.07 ± 0.07 [a]	0.02 ± 0.01 [b]

Table 7. Continued.

C 22:5ω-6	0.02 ± 0.01 [b]	0.03 ± 0.02 [a]	0.02 ± 0.01 [b]
C 22:5ω-3	0.07 ± 0.03 [a]	0.03 ± 0.01 [b]	0.09 ± 0.07 [a]
C 22:6ω-3	0.02 ± 0.01 [a]	0.03 ± 0.01 [a]	0.02 ± 0.01 [a]
Σ PUFA[t]	3.73 ± 0.54 [b]	4.98 ± 0.85 [a]	3.14 ± 0.93 [b]
C 18:2 *c*9, *t*11	1.09 ± 0.21 [a]	0.69 ± 0.19 [b]	1.21 ± 0.13 [a]
C 18:2 *t*10, *c*12	0.01 ± 0.00 [b]	0.03 ± 0.02 [a]	0.01 ± 0.01 [b]
C 18:2 *c*11, *t*13	0.01 ± 0.00 [b]	0.02 ± 0.02 [a]	0.04 ± 0.02 [a]
Σ CLA[t]	1.11 ± 0.21 [a]	0.74 ± 0.19 [b]	1.26 ± 0.14 [a]
C 14:1*t*9	0.22 ± 0.08 [b]	0.26 ± 0.14 [b]	0.35 ± 0.04 [a]
C 16:1*t*9	0.51 ± 0.07 [a]	0.35 ± 0.18 [b]	0.51 ± 0.06 [a]
C 18:1 *t*9	0.04 ± 0.02 [a]	0.02 ± 0.01 [b]	0.04 ± 0.02 [a]
C 18:1 *t*11	3.60 ± 1.02 [b]	9.21 ± 3.22 [a]	4.28 ± 2.01 [b]
C 18:2 *t*9, *t*12	0.28 ± 0.05 [a]	0.08 ± 0.04 [b]	0.22 ± 0.17 [a]
C 18:2 *t*9, *c12*	0.23 ± 0.07 [b]	0.20 ± 0.05 [b]	0.28 ± 0.04 [a]
Σ TFA[t]	4.87 ± 1.03 [b]	10.12 ± 3.13 [a]	5.68 ± 1.96 [b]
Σ ω-3	0.44 ± 0.09 [b]	0.44 ± 0.12 [b]	1.04 ± 0.59 [a]
Σ ω-6	3.30 ± 0.51 [b]	4.53 ± 0.78 [a]	2.11 ± 0.63 [c]
ω-3/ω-6	0.13 ± 0.03 [b]	0.10 ± 0.02 [b]	0.49 ± 0.26 [a]
ω-6/ω-3	7.50 ± 1.56 [b]	10.30 ± 2.18 [a]	2.03 ± 1.13 [c]

[x]Average of three lots analyzed; [y]Values reported are mean ± SD; [z]abc values for each sample with different letters in the same fraction are significantly different at $p < 0.05$. TFA: *trans* fatty acid; CLA: conjugated linoleic acid; [t]SFA: Saturated fatty acid; MUFA: monounsaturated fatty acid; PUFA: polyunsaturated fatty acid.

which is the predominant *trans* monounsaturated fatty acid in ruminant milk and tissue fat (Parodi, 1976; Precht et al., 2001) is formed as an intermediate during the biohydrogenation of dietary linoleic acid to stearic acid (Kepler and Tove, 1967; Jiang et al., 1996).

In the present study, pasture feeding increased total ω3 and ω3/ω6 ratio in perirenal and tail fat. Significant differences were observed between pasture and concentrate groups in tail and perirenal fat for total ω3 and ω3/ω6 ratio ($P < 0.05$). From the nutritional aspect, fat from lambs raised on pasture seems to be more adequate, than that of lambs raised in confinement with concentrate because of their higher proportion on ω3 PUFA and CLA and lower ω6/ω3 ratio (Santos-Silva et al., 2002). In the present study, omental, perirenal and tail fat of concentrate-fed lambs had higher ω6/ω3 ratio and pasture feeding decreased this ratio. The ratio of ω6/ω3 fatty acid was significantly lower in grass fed lamb adipose tissue fat compared with lambs fed with concentrate (Nuernberg et al., 2008). The ω6/ω3 ratio, in perirenal fat (1.87) and tail fat (2.03) from pasture fed lambs was below the recommended level of 4 for human consumption (Deparment of Health, 1994).

In conclusion, fatty acid composition of omental, perirenal and tail fat from Akkaraman lambs were affected by feeding regime. Omental, perirenal and tail fat of lambs fed pasture contained more CLA, total ω3, ω3/ω6 ratio which is beneficial to human health compared with concentrate-fed lambs. Moreover, omental, perirenal and tail fat of lambs fed concentrate had higher ω6/ω3 ratio and pasture feeding decreased this ratio. Fatty acid composition of omental, perirenal and tail fat from lambs can be improved by including pasture in the feeding regime.

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