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FATTY ACIDS IN THE INTRAMUSCULAR FAT OF BERRICHON DU CHER AND SUFFOLK HEAVY LAMBS KEPT IN SEMI-INTENSIVE PRODUCTION SYSTEMS IN SLOVAKIA

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ABSTRACT

The objective of this study was to determine the content of fatty acids (FAs) in the intramuscular fat of heavy lambs of two breeds: Berrichon du Cher (BE) and Suffolk (SF) in a semi-intensive production system with different nutrition management schemes applied (SI1 and SI2) using gas chromatography. Nutrition differed mainly in a short period before the slaughter: BE/SI1 lambs were fed with hay and concentrates, SF/SI2 lambs grazed and suckled a milk. The samples were taken from the *Musculus longissimus dorsi* and the analysis of variance with factors of breed/production system (BE/SI1, SF/SI2) and lamb sex (males, females) was used to study the differences in FAs. The content of essential FAs, linoleic acid and α-linolenic acid summed, was higher in SF/SI2 lambs (6.26 g.100 g^{-1} FAME); this significantly ($P < 0.001$) differed from BE/SI1 lambs (4.64 g.100 g^{-1} FAME). The contents of health beneficial FAs (arachidonic, eicosapentaeonic, docosapentaeonic, docosahexaenoic acids) were also higher in SF/SI2 lambs (2.00, 0.59, 0.83, 0.27 g.100 g^{-1} FAME) and significantly ($P < 0.001$) differed from BE/SI1 lambs (1.15, 0.30, 0.44, 0.13 g.100 g^{-1} FAME). The content of conjugated linoleic acid (health beneficial FA as well) was 1.67 g.100 g^{-1} FAME in SF/SI2 lambs and 1.07 g.100 g^{-1} FAME in BE/SI1lambs ($P < 0.001$). The ratio of *n-6/n-3* polyunsaturated FAs agreed, whilst the ratio of polyunsaturated/saturated FAs did not agree with the recommended values (found better in SF/SI2 lambs).

Key words: sheep; production system; lamb sex; *Musculus longissimus dorsi*; fatty acids

INTRODUCTION

Worldwide, research is focused on revealing the potential benefits from the consumption of lamb meat (Swanson *et al.*, 2012, Mortimer *et al.*, 2014, Ponnampalam *et al.*, 2014). There are many studies assessing the quality of lamb meat on the base of essential fatty acids (FAs), e.g. linoleic acid, α-linolenic acid and health promoting polyunsaturated FAs (PUFA) in the intramuscular and subcutaneous fat (Mortimer *et al.* 2014, Ponnampalam *et al.* 2014). Regarding PUFA, eicosapentaenoic acid and docosahexaenoic acid are believed to be of anti-inflammatory effect, helping to protect the human body against autoimmune diseases (Simopoulos, 2002, McAfee *et al.*, 2010) and to be linked to healthy aging throughout life (Swanson *et al.*, 2012). Conjugated linoleic acid was investigated as well for its anti-carcinogenic, anti-atherosclerotic and

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anti-diabetic effects (Raes *et al.*, 2004; Serra *et al.* 2009). Regarding saturated FAs (SFA), high amounts of myristic acid and palmitic acid are assumed to increase the risk of cardiovascular diseases and of the higher cholesterol level (Howes *et al.*, 2015). On the contrary, high amounts of stearic acid are considered to have no an effect on cholesterol level (Howes *et al.*, 2015). The research was also focused on the determination of recommended values for ratios of PUFA/SFA to be beneficiary for human health: above 0.7 or 0.45 – according to Raes *et al.* (2004) and Williams (2000), or a minimum of 0.4 – according to Wood and Enser (1997), as well as *n-6*/*n-3* PUFA, below 4 – according to Simopoulos (2002) and Wood *et al.* (2003). Investigation of essential FAs revealed that their health beneficial effect depends on both production system and nutrition of lambs (Fisher *et al.*, 2000, Sinanoglou *et al.*, 2013). Díaz *et al.* (2005), Aurousseau *et al.* (2007) and Nuernberg *et al.* (2008) also reported that the content of FAs depends on quality of pasture, hay/silage and concentrates. The content of FAs may also be affected by a genotype of animals; this is believed to be of lesser influence (Santos-Silva *et al.*, 2002, Ponnampalam *et al.*, 2014). Sanudo *et al.* (2000) reported that effects attributed to breed are often due to the degree of fatness, live weight, slaughter age or the production system.

In Slovakia, breeding of various meat and/or non-dairy dual-purpose breeds producing heavy lambs of carcass weight above 13 kg is increasing being about 10 to 15 % of total number of sheep (according to Margetín *et al.*, 2018). Three production systems for fattening of heavy lamb are applied in Slovakia. Traditionally, the indoor lambing system is applied in winter. Lambs are fed with complex feed rations, including hay/silage and concentrate and housed in stables. Since 1990s, a pasture production system becomes important. It is characterised by indoor lambing in spring; lambs are moved with ewes to pasture at an early age, fed with no hay/silage and concentrates. Regardless of a system, lambs are allowed to suckle milk. In addition to these two systems, a semi-intensive production system, as a combination of traditional and pasture systems with indoor lambing, is applied. Lambs with ewes are housed at an early age; nutrition of ewes consists of hay and concentrates; lambs are allowed to suckle milk. When pasture is available, lambs and ewes are pastured; lambs are offered with concentrates when needed. Two weeks before slaughter, lambs are either fed with hay/concentrate or lambs suckle milk and graze. Some research, focused on the analyses of the content of FAs in the intramuscular fat of light and heavy lambs, was done in Slovakia (Margetín *et al.* 2014; 2018). These studies were limited to pastured and stabled animals and did not cover the semi-intensive production system.

Therefore, the objective of this study was to determine the content of FAs in the intramuscular fat (analysed from *Musculus longissimus dorsi* samples) of heavy lambs of two breeds: Berrichon du Cher (BE) and Suffolk (SF) in the semi-intensive production system with different nutrition management schemes applied (SI1 and SI2). In addition to the influence of the overlapping breed/production system factor (BE/SI1 and SF/SI2), the influence of the lamb sex factor on the content of FAs was also investigated.

MATERIAL AND METHODS

Animals and production system

Two groups of heavy lambs (each included 20 heads: 13 males and 7 females): Berichon du Cher (BE) and Suffolk (SF) from two flocks – the semi-intensive production system differing in nutrition management (SI1 and SI2) – were included in the experiment. This design was the only available due to the fact that commercial flocks with an identical semi-intensive system for different breeds cannot be found in Slovakia. The distance between flocks was about 15 km (GPS coordinates of location 1 were 48°43' N and 19°96' E; GPS coordinates of location 2 were 48°34' N and 20°06' E). Both flocks were characterised by a similar height above the sea, annual rainfall and average temperature. The pasture was natural, free of any seed enrichment. The fence system (ewes and lambs grazed together) was applied. Flock size was 94 and 203 breeding females, respectively.

The first group consisted of BE lambs. Ewes lambed indoors, mainly in April; their diet consisted of 2 kg of hay (mixture of alfalfa and grass hay), 3 kg of alfalfa silage and 200 g of oat per head per day. Since birth, lambs were housed with ewes in stable

(maternity pens and nurseries, respectively) and suckled milk. From two to three weeks after birth, in addition to milk, lambs were fed with on-farm grained oat and barley (ratio 1:1) per head per day. Since three weeks after parturition, lambs and ewes were moved to pasture. Lambs were offered on-farm grained oat and barley (100 to 200 g per head per day) when needed. Two weeks before slaughter, lambs were separated from ewes and allowed neither to graze nor suckle milk. They were fed with 200 g of grained oat and barley (ratio 1:1) per head per day; hay was available *ad libitum*. This breed/production system is referred to as BE/SI1 lambs.

The second group consisted of SF lambs. Ewes were lambed indoors, mainly in April; their diet included 2 kg of hay (mixture of alfalfa and grass hay), 3 kg of alfalfa silage and 400 g of concentrates per head per day. Since birth, lambs were housed with ewes in stable (maternity pens and nurseries, respectively) and suckled milk. Until three weeks of age, lambs were also fed with a commercial starter PURINA (Agribrands Europe, Hungary) *ad libitum*, which consisted of dry matter (88 %), NL (16 %), fat (2.2 %), fibre (11 %), Ca (1.3 %), P (0.4 %) and Na (0.3 %) and supplements. Since three weeks after parturition, ewes and lambs were moved to pasture. Instead of PURINA, lambs were offered on-farm grained oat and barley (100 to 200 g per head per day) when needed. Two weeks before slaughter, lambs were only allowed to graze and suckle milk. This breed/production system is referred to as SF/SI2 lambs.

Lambs of both groups were slaughtered in the authorised slaughterhouse run by the National Agricultural and Food Centre – Research Institute of Animal Production Nitra. The average weight before slaughter was 31.8 ± 3.4 kg (BE/S1) and 36.1 ± 5.0 kg (SF/SI2), respectively. The average age of lambs was 86 ± 2.9 days (BE/S1) and 93 ± 6.8 days (SF/SI2), respectively. The average daily gain of lambs was 290 ± 40 g (BE/S1) and 330 ± 50 g (SF/SI2), respectively.

Analysis of fatty acids

Twenty-four hours after slaughter, meat samples were taken from the *Musculus longissimus dorsi* (MLD) between the 9th and 13th vertebra. The analysis of the content of fatty acids (FAs) in the intramuscular fat (IMF) was undertaken in the laboratory of the Institute of Chemistry (Faculty of Natural Sciences at Comenius University in Bratislava), following the procedure described in the study of Margetín *et al.* (2018).

A total of 70 FA were identified. The hypocholesterolaemic FA/hypercholesterolaemic FA ratio (h/H ratio) was calculated according to Santos-Silva *et al.* (2002) and Sinanoglou *et al.* (2013). The atherogenic index (AI) and thrombogenic index (TI) were calculated according to Ulbricht and Southgate (1991) and Sinanoglou *et al.* (2013).

Statistical analysis

Data were analysed using an analysis of variance. General Linear Model procedure as implemented in programme SAS (2009) was applied. The model included: (A) the overlapping breed/production system factor (BE/SI1 and SF/SI2 lambs) due to the fact that variance of breed was hardly possible to be distinguished from variance of production system, and (B) the lamb sex factor (males and females). A preliminary analysis, which included breed/production system–sex interaction, revealed its non-significant influence; thus, this was not considered. Differences in estimated least square means of individual levels of factors included were tested using a Scheffe test and were considered statistically significant in case of $P < 0.05$ or $P < 0.001$.

RESULTS AND DISCUSSION

Analysis of individual fatty acids

Effect of breed/production system

The contents of FAs in IMF of MLD samples from lambs of analysed breed/production systems are shown in Table 1. Regarding individual saturated FAs (SFA), only palmitic acid (PA) was found to be significantly different ($P < 0.001$) between BE/SI1 lambs (23.40 g.100 g^{-1} FAME) and SF/SI2 lambs (21.92 g.100 g^{-1} FAME). In accordance with the studies of Díaz *et al.* (2005), Fiori *et al.* (2013) and Cividini *et al.* (2014), PA was the most common SFA. Although, it is impossible to distinguish between variance accounted for breed and variance accounted for production system, both values were

found within the range as estimated for pastured (21.80 g.100 g^{-1} FAME) and stabled (28.51 g.100 g^{-1} FAME) Ile de France (IF) lambs by Margetín *et al.* (2018). This probably reflects the fact that both breeds in the semi-intensive production systems were allowed to graze and/or had less concentrate supplements in their diet. Moreover, it seems that the content of PA in SF/SI2 lambs decreased to greater extent due to the fact that these lambs were pastured also in the last period of fattening. The content of PA in this study was found to be similar to the content of PA in commercial crossbred castrated males from the United Kingdom (breeds used for this crossbreeding were not given) and male crossbreds between Sufolk or Schwarzköpfe and Merino Landschaf from Germany (both on grass and concentrate supplements), when compared with the findings of Díaz *et al.* (2005). No differences ($P > 0.05$) were found when the contents of remaining SFA i.e. lauric acid, myristic acid, margaric acid and stearic acid (SA) were compared. The contents of these were found to be similar to the values in pastured IF lambs (Margetín *et al.*, 2018). In accordance with the studies of Díaz *et al.* (2005), Fiori *et al.* (2013) and Cividini *et al.* (2014), SA was the second common SFA. In SF/SI2 lambs, this was almost same as in stabled IF lambs (14.46 vs. 14.51 g.100 g^{-1} FAME). In BE/SI1 lambs, this was almost the same as in pastured IF lambs (15.28 vs. 15.65 g.100 g^{-1} FAME), when compared with the study of Margetín *et al.* (2018).

Regarding individual mono-unsaturated FAs (MUFA), oleic acid (OA), *trans*-vaccenic acid (TVA) and palmitoleic acid were found to be of significantly different ($P < 0.001$) content between BE/SI1 and SF/SI2 lambs. The most common MUFA was found OA; its lower content was found in SF/SI2 lambs (31.83 g.100 g^{-1} FAME) than in BE/SI1 lambs (34.02 g.100 g^{-1} FAME). The values reported in this study were slightly higher than Aurousseau *et al.* (2007) reported for lambs on pasture, those diets were enriched with concentrates for a short/long period

Table 1. Least square means of fatty acids in the intramuscular fat (g.100g^{-1} fatty acid methyl esters) of lamb meat

Fatty acids	Breed/Production system		Sex		SEM	R^2
	BE/SI1	SF/SI2	Male	Female		
C12:0 (lauric)	0.59	0.51	0.56	0.55	0.188	0.08
C14:0 (myristic)	5.26	4.80	4.79	5.27	1.111	0.11
C16:0 (palmitic)	23.40^{a}	21.92^{b}	22.25	23.07	1.573	0.26
C17:0 (margaric)	0.98	0.95	0.95	0.98	0.076	0.08
C18:0 (stearic)	15.28	14.46	15.70^{A}	14.04^{B}	1.677	0.25
C16:1 *cis 9* (palmitoleic)	0.52^{a}	0.57^{b}	0.53	0.56	0.057	0.20
C 18:1 *trans 9* (elaidic)	0.26	0.27	0.26	0.27	0.025	0.03
C18:1 *cis 9* (oleic)	34.02^{a}	31.83^{b}	32.48	33.37	2.185	0.28
C18:1 *trans 11* (TVA)	2.11^{A}	2.93^{B}	2.46	2.58	0.308	0.70
C18:2 *n-6* (linoleic)	3.85^{a}	5.08^{b}	4.77	4.16	1.428	0.24
C18:3 *n-6* (GLA)	0.04	0.04	0.05	0.04	0.019	0.08
C18:3 *n-3* (ALA)	0.78^{A}	1.19^{B}	1.01	0.96	0.212	0.56
C18:2 *cis9 trans 11* (RA)	0.96^{A}	1.51^{B}	1.15^{a}	1.32^{b}	0.256	0.57
C20:4 *n-6* (arachidonic)	1.15^{a}	2.00^{b}	1.80	1.36	0.975	0.23
C20:5 *n-3* (EPA)	0.30^{A}	0.59^{B}	0.52	0.37	0.255	0.36
C22:5 *n-3* (DPA)	0.44^{A}	0.83^{B}	0.72	0.55	0.313	0.39
C22:6 *n-3* (DHA)	0.13^{A}	0.27^{B}	0.22	0.18	0.110	0.37

BE/SI1: Berrichon du Cher in semi-intensive system 1; SF/SI2: Suffolk in semi-intensive system 2; SEM: Standard error of mean; R^2: Coefficient of determination.
TVA: *trans*-vaccenic acid; ALA: α-linolenic acid; GLA: γ-linolenic acid; RA: rumenic acid; EPA: eicosapentaeonic acid; DPA: docosapentaeonic acid; DHA: docosahexaeonic acid.
$^{A, B:}$ differences between individual levels of factors at $P < 0.001$; $^{a, b:}$ differences between individual levels of factors at $P < 0.05$.

(28.8 and 29.9 g.100 g^{-1} FAME). Contrariwise, they were slightly lower, than Silva Sobrinho *et al.* (2014) reported for meat of lambs on a diet with a forage/concentrate ratio (1:1). The values reported in this study were higher than Margetín *et al.* (2018) reported for both pastured and stabled lambs. According to Aurousseau *et al.* (2007), it may be expected that the more concentrate in a diet, the more absorption of OA is found. Jenkins (1994) also reported that OA in meat of stabled lambs fed with higher amount of concentrates should be of higher content than in meat of grazed lambs fed with lower amount of concentrates. Nevertheless, OA is mobilised from body fat and its higher contents in both BE/SI1 and SF/SI2 lambs are probably due to the fact that daily gains of these breeds were found higher than daily gains of stabled IF lambs (Margetín *et al.*, 2018). The content of TVA was 2.11 g.100 g^{-1} FAME (BE/SI1 lambs) and 2.93 g.100 g^{-1} FAME (SF/SI2 lambs), respectively. These values were lower than those found in pastured IF lambs, but higher than those found in stabled IF lambs (Margetín *et al.*, 2018). Moreover, the findings about higher contents of TVA (most important precursor of conjugated linoleic acid (CLA)) in meat of grazed lambs (regardless of access to concentrates) agree with the studies of Nuernberg *et al.* (2005) and Aurousseau *et al.* (2007), who found higher contents of TVA in grazed lambs as well. The content of palmitooleic acid was 0.52 g.100 g^{-1} FAME (BE/SI1 lambs) and 0.57 g.100 g^{-1} FAME (SF/SI2 lambs), respectively. Elaidic acid, contrariwise to remaining individual MUFA, showed no difference ($P > 0.05$) between meat of two lamb groups (0.26 and 0.27 g.100 g^{-1} FAME). Similarly, Margetín *et al.* (2018) reported no difference between meats of pastured and stabled IF lambs (0.28 g.100 g^{-1} FAME, both) as far as the content of this individual MUFA is related.

Regarding individual polyunsaturated FAs (PUFA), γ-linolenic acid (GLA) was PUFA of the lowest content in analysed lamb groups (0.04 g.100 g^{-1} FAME in both, i.e. no difference observed, $P > 0.05$). The remaining individual PUFA significantly differed ($P < 0.001$, $P < 0.05$) between these two lamb groups. The essential linoleic acid (LA) was PUFA of the highest content i.e. 3.85 g.100 g^{-1} FAME (BE/SI1 lambs) and 5.08 g.100 g^{-1} FAME (SF/SI2 lambs), respectively. The content of essential α-linolenic acid (ALA) was 0.78 g.100 g^{-1} FAME (BE/SI1 lambs) and 1.19 g.100 g^{-1} FAME (SF/SI2 lambs), respectively. The content of rumen acid (RA) was 0.96 g.100 g^{-1} FAME (BE/SI1 lambs) and 1.51 g.100 g^{-1} FAME (SF/SI2 lambs). The contents of health beneficial PUFA i.e. arachidonic acid (AA), eicosapentaeonic acid (EPA), docosapentaeonic (DPA) and docosahexaeonic acid (DHA) were following: 1.15, 0.30, 0.44 and 0.13 g.100 g^{-1} FAME (BE/SI1 lambs) and 2.00, 0.59, 0.83 and 0.27 (SF/SI2 lambs). Except for ALA and AA, the remaining PUFA followed the expected pattern and fell within the range given by values for stabled and pastured IF animals (Margetín *et al.*, 2018). In general (with few exceptions), meat of lambs partly allowed to graze (regardless of breed) is of more favourable content of FAs (individual SFA, MUFA and PUFA investigated) than the meat of stabled lambs, although this is of slightly lower quality than the meat of lambs grazed, with no concentrates in their diet).

Effect of lamb sex

The content of FAs, as affected by lamb sex, is shown in Table 1. Comparisons within individual SFA, MUFA and PUFA revealed significant differences ($P < 0.001$, $P < 0.05$) between males and females only in the contents of SA and RA, i.e. SA was found higher in males (15.70 g.100 g^{-1} FAME) than in females (14.04 g.100 g^{-1} FAME), while RA was found higher in females (1.32 g.100 g^{-1} FAME) than in males (1.15 g.100 g^{-1} FAME), following the same tendency as observed by Margetín *et al.* (2018). Regarding remaining individual SFA, MUFA and PUFA, no pattern in their content was found. About half of FAs tended to be of higher content in males, but these difference were negligible.

Analysis of groups of fatty acids, their ratios and indexes

Effect of breed/production system

The contents of FA groups (SFA, MUFA, PUFA, etc.), their ratios and indexes (as affected by breed/production system) are shown in Table 2. The content of SFA group was 48.59 g.100 g^{-1} FAME (BE/SI1 lambs) and 45.57 g.100 g^{-1} FAME (SF/SI2 lambs), respectively. The content of MUFA group was 42.10 g.100 g^{-1} FAME (BE/SI1lambs) and 40.77 g.100 g^{-1} FAME (SF/SI2 lambs), respectively. The content of PUFA group was 9.30 g.100 g^{-1} FAME (BE/SI1 lambs) and 13.66 g.100 g^{-1} FAME (SF/SI2 lambs), respectively. Except for MUFA group, the differences were significant ($P < 0.001$).

Except for SFA group (both values similar to pastured IF lambs), the values for MUFA and PUFA groups were within the values for stabled and pastured IF animals as reported by Margetín *et al.* (2018). The values of SFA, MUFA and PUFA groups were also similar to the values reported by Díaz *et al.* (2005) for male crossbreds (grazed and fed with concentrates) from the United Kingdom and Germany. Health benefits of lamb meat (similarly to other types of red meat), were questioned due to its relatively high content of SFA and relatively low content of PUFA (McAfee *et al.*, 2010, Howes *et al.*, 2015). Regarding contents of *cis*-UFA (38.06 and 36.59 g.100 g^{-1} FAME in BE/SI1 and SF/SI2 lambs) and *trans*-UFA (4.84 and 5.65 g.100 g^{-1} FAME in BE/SI1 and SF/SI2 lambs), these were similar to values for stabled (on a diet with concentrates) and pastured IF lambs (for comparison, see Margetín *et al.*, 2018). The contents of branched-chain FAs were 1.95 g.100 g^{-1} FAME (BE/SI1 lambs) and 1.80 g.100 g^{-1} FAME (SF/SI2 lambs) and were higher than Aurousseau *et al.* (2007) reported for grazed IF male crossbreds, fed with hay and concentrates either a short (22 days) or long (41 days) period before

Table 2. Least square means of fatty acid groups, their ratios and indexes in the intramuscular fat (g.100g^{-1} fatty acid methyl esters)

Fatty acids	Breed/Production system		Sex		SEM	R^2
	BE/SI1	SF/SI2	Male	Female		
SFA[1]	48.59^{A}	45.57^{B}	47.23	46.94	2.630	0.31
MUFA[2]	42.10	40.77	40.64	42.22	2.457	0.17
PUFA[3]	9.30^{A}	13.66^{B}	12.13	10.83	3.248	0.39
Trans-UFA[4]	4.84^{A}	5.65^{B}	5.10^{a}	5.38^{b}	0.424	0.55
Cis-UFA[5]	38.06	36.59	36.60	38.05	2.386	0.19
BCFA (*iso, anteiso*)[6]	1.95^{a}	1.80^{b}	1.82	1.94	0.195	0.21
Essential FA (LA+ALA)	4.64^{A}	6.26^{B}	5.79	5.11	1.592	0.30
n-6 PUFA[7]	5.18^{a}	7.33^{b}	6.81	5.70	2.486	0.24
n-3 PUFA[8]	1.76^{A}	3.01^{B}	2.62	2.16	0.883	0.44
CLA[9]	1.07^{A}	1.67^{B}	1.28^{a}	1.46^{b}	0.274	0.58
PUFA/SFA	0.19^{A}	0.30^{B}	0.26	0.23	0.087	0.37
∑*n-6* /∑*n-3* PUFA	2.94^{A}	2.40^{B}	2.72	2.62	0.301	0.50
LA/ALA	4.98^{a}	4.22^{b}	4.84	4.36	0.875	0.23
LC *n-6* /LC *n-3* PUFA[10]	1.32^{a}	1.18^{b}	1.29	1.22	0.189	0.18
AI (atherogenic index)	0.93	0.82	0.85	0.89	0.159	0.16
TI (thrombogenic index)	1.51^{A}	1.25^{B}	1.37	1.39	0.184	0.41
h/H[11] index	1.44	1.58	1.56	1.46	0.240	0.15

[1]SFA is the sum of saturated fatty acids: C8:0 + C10:0 + C11:0 + C12:0 + C13:0 + *iso*C14:0 + C14:0 + *iso*C15:0 + *anteiso*C15:0 + C15:0 + *iso*C16:0 + C16:0 + *iso*C17:0 + *anteiso*C17:0 + C17:0 + *iso*C18:0 + C18:0 + C19:0 + C20:0 + C21:0 + C22:0; [2]MUFA, sum of monounsaturated FA: C12:1 + C14:1 + *t*C16:1 + *c*C16:1 + 9*c*C16:1 + C17:1 + 6-8*t*C18:1 + 9*t*C18:1 + 10*t*C18:1 + 11*t*C18:1 + 12*t*C18:1 + 9*c*C18:1 + (15*t*+11*c*C18:1) + 12*c*C18:1 + 13*c*C18:1 + (14*c*C18:1+9*t*12*t*18:2 / 2) + 15*c*C18:1 + (C18:2+C19:1 / 2) + C20:1; [3]PUFA is the sum of polyunsaturated FA: (14*c*C18:1+ 9*t*12*t*18:2 / 2) + 9*c*13*t*C18:2 + (8*t*13*c*+9*c*12*t*C18:2) + (9*t*12*c* + 11*t*15*c*C18:2) + C18:2*n-6* + 9*c*15*c*C18:2 + 12*c*15*c*C18:2 + *cc*C18:2 + *cc*C18:2 + (C18:3 *n-6* GLA) + (C18:2+C19:1 / 2) + cyklo + 9*t*12*c*15*c*C18:3 + C18:3 *n-3* + (9*c*11*t*C18:2 CLA) + *ct*CLA + *cc*CLA + *tc*CLA + *tt*CLA + C18:3 + C20:2 + C20:3 *n-9* + C20:3 *n-6* + C20:4 *n-6* + C20:3 *n-3* + C20:4 *n-3* + C20:5 *n-3* + furyl C22 + C22:4 *n-3* + C22:5 *n-3* + C22:6 *n-3*; [4]*Trans* UFA is the sum of *trans*UFA: *t*C16:1 + 6-8*t*C18:1+ 9*t*C18:1+ 10*t*C18:1 + 11*t*C18:1 + 12*t*C18:1 +((15*t*+11*c*C18:1/3)*2) + (14*c*C18:1+ 9*t*12*t*18:2 / 2) + 9*c*13*t*C18:2 + (8*t*13*c*+9*c*12*t*C18:2) + 9*t*12*c*+11*t*15*c*C18:2 + *tt*CLA; [5]Cis-UFA is the sum of cis-UFA: *c*C16:1 + 9*c*C16:1 + 9*c*C18:1 + (15*t*+11*c*C18:1 / 3) + 12*c*C18:1 + 13*c*C18:1 + (14*c*C18:1+ 9*t*12*t*C18:2 / 2) + 15*c*C18:1 + 9*c*15*c*C18:2 + 12*c*15*c*18:2 + *cc*C18:2 + *cc*C18:2 + 9*c*11*t*C18:2 CLA + *ct*CLA + *cc*CLA + *tc*CLA; [6]BCFA is the sum of *iso and anteiso* FA: *iso*C14:0 + *iso*C15:0 + *anteiso*C15:0 + *iso*C16:0 + *iso*C17:0 + *anteiso*C17:0 + *iso*C18:0; [7]*n-6* PUFA is the sum of *n-6* PUFA: C18:2 *n-6* + C18:3 *n-6* GLA + C20:3 *n-6* + C20:4 *n-6*; [8]*n-3* PUFA is the sum of *n-3* PUFA: C18:3 *n-3* + C20:3 *n-3* + C20:4 *n-3* + C20:5 *n-3* + C22:4 *n-3* + C22:5 *n-3* + C22:6 *n-3*; [9]CLA = 9*c*11*t*C18:2 CLA + *ct*CLA + *cc*CLA + *tc*CLA + *tt*CLA; [10]LC *n-6* PUFA = *n-6* PUFA – LA and [10]LC *n-3* PUFA = *n-3* PUFA – ALA; [11]h/H=hypocholesterolaemic FA/hypercholesterolaemic FA. For remaining explanations see Table1.

the slaughter (1.3 and 1.5 g.100 g^{-1} FAME, respectively). When comparing with the study of Margetín *et al.* (2018), both contents of *n-6* PUFA and *n-3* PUFA for SF/SI2 lambs (7.33 and 3.01 g.100 g^{-1} FAME) were slightly lower than respective contents found for pastured IF animals (8.50 and 4.55 g.100 g^{-1} FAME).

The content of essential FAs (summed LA and ALA) was 4.64 g.100 g^{-1} FAME (BE/SI1 lambs) and 6.26 g.100 g^{-1} FAME (SF/SI2lambs), respectively. The content of CLA was 1.07 g.100 g^{-1} FAME (BE/SI1 lambs) and 1.67 g.100 g^{-1} FAME (SF/SI2 lambs), respectively. The contents of summed LA and ALA as well as CLA tend to accord both with respective values for stabled and pastured IF lambs (Margetín *et al.*, 2018). The contents of CLA, moreover, roughly agreed with Díaz *et al.* (2005) reported for male lamb crossbreds on a grass diet supplemented with hay and concentrates (0.97 and 1.05 g.100 g^{-1} FAME) and roughly agreed with the recommendation of Raes *et al.* (2004), which was less than or almost equal to 1.0 g.100 g^{-1} FAME). The findings about CLA also agreed with Daley *et al.* (2010), who showed that grass-based diets increase its amount in meat.

The ratios and indexes of FA groups that may help in assessing both nutrition value of lipids and their benefits from human health point of view are shown in Table 2. The ratios of *n-6*/*n-3* PUFA were 2.94 (BE/SI1 lambs) and 2.40 (SF/SI2 lambs); they agreed with the recommendation to be below 4, as proposed by Simpoulos (2002) and Wood *et al.* (2003). These ratios were higher than Aurosseau *et al.* (2007) reported for grazed IF male lambs, supplementally fed with hay and concentrates (1.7 and 2.2). The ratios of LC *n-6*/LC *n-3* PUFA were 1.32 (BE/SI1 lambs) and 1.18 (SF/SI2 lambs) and were higher than or almost equal as Aurosseau *et al.* (2007) reported (0.8 and 1.2). The ratios of PUFA/SFA were 0.19 (BE/SI1 lambs) and 0.30 (SF/SI2 lambs), i.e. differed from the recommendations to be above 0.7 (proposed by Raes *et al.*, 2004) or above 0.45 (proposed by Williams, 2000) or to be 0.4 at a minimum (proposed by Wood and Enser, 1997). The atherogenic index (AI) was found to be close to 1 (0.93 and 0.92, respectively) and agreed with the recommendation of Sinanoglu *et al.* (2013), who proposed this index to be 1 at a maximum. The same recommendation was proposed for thrombogenic index (TI); this was, however, slightly higher, i.e. 1.51 (BE/SI1lambs) and 1.25 (SF/SI2 lambs), respectively. The latter was almost the same as TI reported by Margetín *et al.* (2018) for pastured IF lambs (1.24). Taking into account especially AI ratios, meat of both lamb groups should be considered as healthy food consisting of beneficial FAs that may help in prevention of cardiovascular diseases (Margetín *et al.*, 2018). The ratios of hypocholesterolaemic FA/hypercholesterolaemic FA (h/H) were 1.44 (BE/SI1 lambs) and 1.58 (SF/S2 lambs), i.e. similar to h/H reported by Margetín *et al.* (2018) for pastured IF lambs (1.38).

Effect of lamb sex

The contents of FA groups, their ratios and indexes (as affected by lamb sex) are shown in Table 2. Significant differences ($P < 0.05$) between males and females were found only in the contents of *trans*-UFA, i.e. 5.10 g.100 g^{-1} FAME (males) and 5.38 g.100 g^{-1} FAME (females) and CLA, i.e. 1.28 g.100 g^{-1} FAME (males) and 1.46 g.100 g^{-1} FAME (females), following the same tendency as observed by Margetín *et al.* (2018). Regarding remaining SFA, MUFA and PUFA groups, studied ratios and indexes, no pattern was found. About half tended to be higher in males but these differences were negligible.

Coefficients of determination

The coefficients of determination (R^2), calculated for the models analysing individual fatty acids as well as their groups, various ratios and indexes in BE/SI1 and SF/SI2 lambs (ranged from 0.03 to 0.70 and from 0.15 to 0.58), were lower than R^2 reported by Margetín *et al.* (2018) for pastured and stabled IF lambs (ranged from 0.15 to 0.92 and from 0.11 to 0.90). These findings are not easy to explain; probably they are due to the fact that the models were of less precision (regarding possible factors known). Moreover, individual differences among observations tend to be higher than those accounted for systematic effects.

CONCLUSION

Analyses of fatty acids indicate that lamb meat of both breeds in the semi-intensive production systems differing in nutrition management schemes seems to be of good quality i.e. the lower contents of individual SFA (or SFA group as well) and the higher contents of individual MUFA and PUFA (or MUFA and PUFA groups as well) were found. In spite of a few exceptions, meat of lambs that were pastured (no concentrates in a diet) also in a short period before slaughter showed a slightly better composition of fatty acids. Meat of both lamb groups, however, may be recommended for human consumption.

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