Fatty Acids Profile of Intramuscular Fat in Light Lambs Traditionally and Artificially Reared

Profil mastných kyselín intramuskulárneho tuku ľahkých jatočných jahniat z tradičného a umelého odchovu

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Abstract

The quality of 40 carcasses of light lambs of the synthetic population of Slovak Dairy sheep from (a) artificial rearing (AR) and (b) traditional rearing (TR) was assessed on the basis of fatty acids profile of intramuscular fat (IMF). Lambs from AR in comparison with TR were of lower quality as assessed on the basis of fatty acids (FAs) profile. The content of conjugated linolic acid (CLA) in the fat of TR lambs was severalfold higher (0.749 vs. 0.193 g.100g^{-1} FAME, P<0.001) than in AR lambs. Similarly, the content of trans-vaccenic (TVA), α-linolenic (ALA), rumenic (RA), eicosapentaenoic (EPA) and docosahexaenoic acid (DHA) was in TR lambs significantly higher (P<0.001) than in AR lambs (0.955 vs. 0.111; 0.715 vs. 0.251; 0.672 vs. 0.148; 0.352 vs. 0.061; 0.252 vs. 0.079 g.100g^{-1} FAME). In contrary, the content of linoleic acid (LA), the ratio of LA/ALA and n-6/n-3 in AR lambs was higher than in TR lambs (9.07 vs. 4.81 g.100 g^{-1} FAME; 39.11 vs. 6.80; 14.56 vs. 3.25, P<0.001). In TR lambs the content of *n-3* PUFA and BCFA was significantly higher (P<0.001) than in AR lambs (2.08 vs. 0.84 and 1.95 vs. 0.45). The value of thrombogenic index was higher in AR lambs in comparison with TR lambs (1.44 vs. 1.31; P<0.05). Significant differences between FAs of IMF of ram lambs and ewe lambs were observed only in the case of arachidonic acid (P<0.05).

Keywords: sheep, light lambs, artificial and traditional rearing, carcass, meat quality, intramuscular fat, fatty acids, CLA

Abstrakt

Cieľm práce bolo posúdiť kvalitu 40 ľahkých jatočných jahniat syntetickej populácie slovenskej dojnej ovce z (a) tradičného odchovu (TO) a (b) umelého odchovu (UO) na základe stanovenia obsahu mastných v intramuskulárnom tuku najdlhšieho chrbtového svalu. Jatočné jahňatá z UO nedosahovali kvalitu jahniat z TO. Obsah konjugovanej kyseliny linolovej (CLA) bol štatisticky vysoko významne (P<0,001)

vyšší v intramuskulárnom tuku jahniat z TO ako v tuku jahniat z UO (0,749 vs. 0,193 g.100 g^{-1} FAME). Obsah kyseliny trans-vakcénovej (TVA), α-linolénovej (ALA), rumenovej (RA), eikozapentaénovej (EPA) a dokozahexaénonej (DHA) bol štatisticky vysoko významne (P<0,001) vyšší pri jahňatách z TO ako pri jahňatách z UO (0,955 vs. 0,111; 0,715 vs. 0,251; 0,672 vs. 0,148; 0,352 vs. 0,061; 0,252 vs. 0,079 g.100g^{-1} FAME). Obsah kyseliny linolovej (LA), podiel LA/ALA a podiel omega-6/omega-3 polynenasýtených mastných kyselín bol štatisticky vysoko významne (P<0,001) vyšší pri jahňatách z UO ako pri jahňatách z TO (9,07 vs. 4,81 g.100g^{-1} FAME; 39,11 vs. 6,80; 14,56 vs. 3,25). Pri jahňatách z TO bol obsah omega-3 polynenasýtených mastných kyselín a mastných kyselín s rozvetveným reťazcom štatisticky vysoko významne (P<0,001) vyšší ako pri jahňatách z UO (2,08 vs. 0,84 a 1,95 vs. 0,45). Index trombogenecity bol štatisticky významne (P<0,05) vyšší pri jahňatách z UO ako pri jahňatách z TO (1,44 vs. 1,31). Efekt pohlavia mal štatisticky významný (P<0,05) vplyv iba na obsah kyseliny arachidonovej.

Detailný abstrakt

Cieľom práce bolo posúdiť kvalitu 40 ľahkých jatočných jahniat syntetickej populácie slovenskej dojnej ovce na základe stanovenia obsahu mastných kyselín v intramuskulárnom tuku najdlhšieho chrbtového svalu. Do pokusu bolo zaradených 20 jahniat z umelého odchovu a 20 jahniat z tradičného odchovu s využitím dôsledneho škôlkovania (v oboch systémoch chovu bolo 13 barančekov a 7 jahničiek). V umelom odchove (UO) boli jahňatá od 2. až 4. dňa po narodení kŕmené mliečnou zmesou, ad libitne mali prístup k ďatelino-trávnemu senu a kŕmnej zmesi pre jahňatá. V tradičnom odchove (TO) bol jahňatám postupne obmedzovaný prístup k mliečnej žľaze matiek: jahňatá boli zatvárané v škôlkach, pričom mladšie jahňatá sa k matkám púšťali častejšie ako staršie. Základná kŕmna dávka bahníc pozostávala z lúčneho a lucernového sena, kukuričnej siláže a kompletnej kŕmnej zmesi. Jahňatá v škôlkach mali k dispozícii to isté objemové a jadrové krmivo ako jahňatá v umelom odchove. Analýza mastných kyselín sa robila v laboratóriu Chemického ústavu Prírodovedeckej fakulty Univerzity Komenského v Bratislave. Na zhodnotenie vplyvu spôsobu odchovu a pohlavia jahniat, resp. interakcie týchto efektov na obsah mastných kyselín bola použitá analýza rozptylu. Priemery odhadnuté metódou najmenších štvorcov boli porovnané Scheffeho testom. Na základe stanoveného obsahu mastných kyselín možno konštatovať, že jahňatá z UO mali v porovnaní s jahňatami z TO nižšiu kvalitu mäsa. Obsah konjugovanej kyseliny linolovej (CLA) bol štatisticky vysoko významne (P<0,001) vyšší v intramuskulárnom tuku jahniat z TO ako v tuku jahniat z UO (0,749 vs. 0,193 g.100 g^{-1} FAME). Obsah kyseliny trans-vakcénovej (TVA), α-linolénovej (ALA), rumenovej (RA), eikozapentaénovej (EPA) a dokozahexaénonej (DHA) bol štatisticky vysoko významne (P<0,001) vyšší pri jahňatách z TO ako pri jahňatách z UO (0,955 vs. 0,111; 0,715 vs. 0,251; 0,672 vs. 0,148; 0,352 vs. 0,061; 0,252 vs. 0,079 g.100 g^{-1} FAME). Obsah kyseliny linolovej (LA), podiel LA/ALA a podiel omega-6/omega-3 polynenasýtených mastných kyselín bol štatisticky vysoko významne (P<0,001) vyšší pri jahňatách z UO ako pri jahňatách z TO (9,07 vs. 4,81 g.100 g^{-1} FAME; 39,11 vs. 6,80; 14,56 vs. 3,25). Pri jahňatách z TO bol obsah omega-3 polynenasýtených mastných kyselín a mastných kyselín s rozvetveným reťazcom štatisticky vysoko významne (P<0,001) vyšší ako pri jahňatách z UO (2,08 vs. 0,84 a 1,95 vs. 0,45). Index trombogenecity bol štatisticky

významne (P<0,05) vyšší pri jahňatách z UO ako pri jahňatách z TO (1,44 vs. 1,31). Efekt pohlavia mal štatisticky významný (P<0,05) vplyv iba na obsah kyseliny arachidonovej.

Kľúčové slová: ovce, ľahké jahňatá, tradičný a umelý odchov, jatočné telo, kvalita mäsa, intramuskulárny tuk, mastné kyseliny, CLA

Introduction

Similarly to Mediterranean and Balkan countries, where dairy sheep prevail and suckling lambs are sold on Easter or Christmas (Sanudo et al., 2000; Lanza et al., 2006; Sinanoglou et al., 2013), dairy sheep are also the most important branch of sheep production in Slovakia. Suckling lambs are mostly weaned at an age of 30 to 45 days (Margetín and Michalík, 1998). Light lambs of carcass weight up to 13 kg are produced mainly before Easter; Christmas lambs are produced to a lesser extent. About 80% of lambs are exported because of a good market price. Two rearing systems can be found. Artificial rearing based on a commercial milk replacer is applied in highly productive dairy breeds; first month lactation revenues from sold milk tend to be higher than lamb costs. Traditional rearing, often applied with nurseries, may be found in less productive dairy breeds (Margetín 2007; Margetín et al. 2009); ewes are milked when lamb weaning is finished.

Lamb meat is required to have not only desirable carcass characteristics but also desirable physico-chemical and senzoric characteristics (Martinez-Cerezo et al., 2005). It is considered to be a highly nutritious, easy digestible and valued food with a positive fatty acid composition (Milewski, 2006; Nuernberg et al., 2008). Many papers (Díaz et al., 2005; Arsenos et al., 2006; Tejeda et al., 2008; Juarez et al., 2008) deal with fatty acids, mainly health-promoting and disease-preventing fatty acids (functional food compounds). Of these, conjugated linolic acid and its isomers which can be found in ruminant milk and meat have anticarcinogenic, antiatherogenic, antidiabetic and other positive characteristics (Cruz-Hernandez et al., 2007).

Quality of light lambs assessed on a basis of fatty acid profiles in intramuscular fat and nutritious value of meat depend on lamb nutrition i.e. quality of mother's milk and quality of roughage and concentrate feed. A feed ration composition may influence the fatty acid profiles (Wood et al., 2003; Lanza et. al., 2006; Nuernberg et al., 2008; Jerónimo et. al., 2009) and carcass quality (Bas and Morand-Fehr, 2000; Díaz et al., 2005; Arsenos et al., 2006; Vasta et al., 2008). An impact of mother's milk on a fatty acid composition in weaned lambs was studied by Zygoyiannis et. al. (1985), Velasco et al. (2004) and Juárez et al. (2009).

No sufficient information on quality and composition of lamb meat is available. Fattening and carcass traits are known; knowledge on physico-chemical and senzoric characteristics is limited. Information on fatty acid composition in Slovak lambs is missing. The objective of this study was, therefore, to assess the quality of light lambs on a basis of their fatty acid profiles in intramuscular fat. Artificially and traditionally reared male and female lambs were compared. Samples were taken from *Musculus longissimus dorsi* and analysed.

Material and Methods

The two groups of light lambs of the synthetic population of Slovak Dairy sheep breed kept in the experimental farm of the Animal Production Research Centre Nitra (APRC Nitra) were included in the experiment. The first group consisted of 20 artificially reared (AR) lambs: 13 males and 7 females. Lambs were separated from their mothers 2 to 4 days after parturition and were fed a commercial milk replacer (Profilamm, supplier Milki, Ltd.) available from an automatic feeding machine (producer Förster-Technik, supplier Agrostar, Ltd.). Lambs were allowed good quality alfalfa-grass hay plus a compound feed ration (OV 02) *ad libitum*. The milk replacer consisted of 33 % dried whey, 24 % refined vegetable oil (coconut nad palmic), 15% partly decarbohydronated dried whey, 10 % wheat protein concentrate, 5 % soybean protein concentrate, 5 % dried whey protein, 5 % wheat starch and 3 % additives (24 % NL, 24 % fat, 8.3 % ash, 1.8 % lysine, 0.5 % dietary fiber, 1.2 % Ca, 0.7 % P and 0.4 % Na). The supplemental compound feed ration (OV 02) consisted of barley, wheat, maize, soybean meal, dried whey, calcium carbonate and additives (18 % NL, 2.4 % fat, 4 % dietary fiber, 4 % ash).

The second group consisted of 20 traditionally reared (TR) lambs: 13 males and 7 females. Lambs were housed with ewes; simultaneously, nurseries were applied. The access to mothers was gradually diminishing and time of separation of lambs from ewes in nurseries was increasing. Younger lambs were allowed to stay with ewes more often than older lambs (Margetín 2007; Margetín et al., 2009, 2010). The basic feed ration of ewes consisted of meadow and lucerne hay, and maize silage plus a compound feed ration (OV 05) with 150 $g.kg^{-1}$ NL at minimum, 100 $g.kg^{-1}$ diet fiber, 60 $g.kg^{-1}$ fat and 100 $g.kg^{-1}$ ash at maximum, 5.3 $g.kg^{-1}$ Na, 9.2 $g.kg^{-1}$ Ca, 7.1 $g.kg^{-1}$ P, 9.3 $g.kg^{-1}$ S and 2.8 $g.kg^{-1}$ Mg at minimum. Lambs in nurseries were fed the same forage and concentrate feed as AR lambs.

AR and TR lambs were slaughtered in the slaughter house of APRC Nitra. The average empty live weight of lambs before killing was 17.9 ± 1.5 kg (average weight of male lambs was 18.5 kg and weight of female lambs was 16.9 kg) and the average age was 59.5 ± 6.6 days. There were found no significant differences in lamb weight (17.8 vs. 17.6 in AR and TR lambs). The differences in age were found significant (63.6 vs. 55.3 days in AR and TR lambs, respectively). Twenty-four hours after slaughter, meat samples were taken from *Musculus longissimus dorsi* (MLD) of each lamb to determine the fatty acid profiles in intramuscular fat (IMT). The analysis was done in the laboratory of the Chemical Institute of the Faculty of Natural Sciences (Comenius University in Bratislava). After removing the epimysium, the 100 g of MLD was minced, vacuum packed and stored at -25°C until lipid analysis. The content of approximately 70 fatty acids was analyzed using capillary gas chromatography. The lipids from 0.5 g meat samples were extracted using 2 mL chloroform-methanol mixtures (2:1 $vol.vol^{-1}$) for 1 hour on rotary shaker. Then was added 1 mL of saline water for better separation of chloroform layer, and 5 min centrifuged at 2000 g. The 1 mL of lower chloroform layers with extracted lipid were filtered through anhydrous sodium sulfate, and then dried and stored under nitrogen at -18 °C. For the preparation of fatty acid methyl esters (FAME), the base-catalyzed methylation procedure with a solution of sodium methoxide in methanol was used. Gas chromatographic (GC) analyses of intramuscular lipid of lamb meat were performed on the gas chromatograph Agilent Technologies 6890N (Agilent, Waldbronn, Germany) with flame ionization detector and a 5973 Network mass-selective detector. FAME were separated in a capillary column 100 m x 0.25 mm i.d. x 0.2 μm film thickness of HP-88 stationary phase (J&W Scientific, Agilent Technologies, CA, USA). The initial column temperature of the programmed run was set to 45 °C and

was held for 2 min, then followed by a step up ramp of 15 °C.min^{-1} to 145 °C, and then of 5 °C.min^{-1} to 240 °C and held for 5 min. Helium was used as the carrier gas with a linear velocity set at 20 cm.s^{-1}. Two µL samples, which represented approximately 10 mg.mL^{-1} FAME, were injected using a split 50:1 at injection temperature 300 °C. Separated fatty acids were identified by reference materials, published retention data and mass spectrometric measurements. The chromatograms were evaluated quantitatively using a method of internal normalization and published response factors of flame ionization detector for FAME (Ackman, 2002). The fatty acid composition of IMF was expressed in grams of each individual FAME per 100 grams of sum detected FAME. The average relative standard deviation of analyzed FAME with content > 0.5 g.100 g^{-1} was 1.1%, for the whole analytical procedure and 5 replicate samples. The content of most important fatty acids affecting human health is shown in Table 1. Fatty acids were grouped by type (saturated, monounsaturated and polyunsaturated fatty acids), and characteristic ratios and indexes were calculated. These values are shown in Table 2. A hypocholesterolaemic fatty acids/hypercholesterolaemic fatty acids ratio (h/H ratio) was calculated according to Santos-Silva et al. (2002) and Sinanoglou (2013). Aherogenic index (AI) and thrombogenic index (TI) were calculated according to Ulbrich and Southgate (1991), and Sinanoglou et al. (2013). A content of desirable fatty acids (DFA) was calculated according to Díaz et al. (2002).
Statistical analyses were done using the analysis of variation. The influence of rearing system (AR and TR), lamb sex (males and females) and interation considered between rearing system and lamb sex on the fatty acid profiles was studied. Estimated least squares means were compared using Scheffe's tests. General Linear Model procedure as implemented in programme SAS (2009) was applied.

Results and Discussion

The fatty acid composition (only some fatty acids were taken into account) as affected by rearing system and lamb sex is shown in Table 1. Rearing system statistically significantly influenced the content of all investigated fatty acids. Similarly to Sinanoglou et al. (2013), the prevailing fatty acids were found myristic acid (MA), palmitic acid (PA) and stearic acid (SA). The important finding is the significantly ($P<0.01$) higher content of PA, which is acid with undesirable effect on human health (mainly cardiovascular diseases), in AR lambs (26.68 g.100g^{-1} FAME) than in TR lambs (22.97 g.100 g^{-1} FAME, Table 1). The content of MA, which is also acid with udesirable effect on human health, did not significantly differed between Slovak AR and TR lambs (5.21 vs. 5.31 g.100 g^{-1} FAME). Lanza et al. (2006) found the slightly lower content of MA in AR (3.08 g.100g^{-1} FAME) and TR lambs (4.11 g.100g^{-1} FAME), respectively. Lambs in the research of Lanza et al. (2006) were only on ewe's milk or on a milk replacer, whereas AR lambs in the presented study were also provided with roughage and concentrate diets. The lower values of MA content were also found by Serra et al. (2009) and Sinanoglou et al. (2013), who reported MA ranging from 2.96 to 4.25 g.100 g^{-1} FAME and from 3.71 to 5.22 g.100 g^{-1} FAME, respectively; the higher content of MA in suckling lambs was found by Oriani et al. (2005), Scerra et al. (2007) and Vacca et al. (2008). The content of SA (Table 1), which is acid with desirable effect on human health, was found significantly ($P<0.001$) higher in TR lambs (10.14 vs. 12.68 g.100g^{-1} FAME).

With monounsaturated fatty acids (MUFA), the highest content of oleic acid (OA) was found. The significantly ($P<0.01$) higher content of OA was found in AR lambs than in TR lambs (37.87 vs. 35.44 g.100 g^{-1} FAME). These values are in accordance with findings of Sinanoglou (2013); they also accorded with findings of Vacca et al. (2008) for light Sarda lambs slaughtered at an age of 40 days and Osorio et al. (2007) for suckling Churra lambs raised on a milk replacer. The content of monounsaturated trans-vaccenic acid (TVA), which is most important precursor of conjugated linolic acid (CLA), was several-fold higher in TR lambs than in AR lambs (Table 1). The content of essencial linolic acid (LA) was two-fold higher in AR lambs than in TR lamb. This is probably due to the fact that milk replacer used for diet of AR lambs consisted of high percentages of coconut and palmic oil, which are commonly known for high LA content (Napolitano et al., 2002; Osorio et al., 2007). The content of the other essential fatty acid, α-linolenic acid (ALA), was almost three-fold higher ($P<0.001$) in TR lambs (0.715 g.100 g^{-1} FAME) than in AR lambs (0.251 g.100 g^{-1} FAME). An even higher difference in ALA content (in IMT of MLD) between lambs fed ewe's milk and lambs raised on a milk replacer was found by Osorio et al. (2007). The crucial finding of this study is also finding about a lower content of rumenic acid ($P<0.001$) in AR lambs than in TR lambs (0.148 vs. 0.672 g.100 g^{-1} FAME). This acid is an important isomer of CLA with anticarcinogenic, antisclerotic, immunomodulatory and other effects on human health. Similarly, Lanza et al. (2006) found several-fold higher content of RA in lambs fed ewe's milk than in lambs raised on a milk replacer (1.13 vs. 0.47 g.100 g^{-1} FAME).

The other crucial finding pointing to a desirable effect of fatty acids of lamb meat on health (Table 1) is the higher content of long chain polyunsaturated fatty acids (PUFA) i.e. of eicosapentaenoic acid (EPA), of docosapentaeonic (DPA) and of docosahexaenoic acid (DHA) in TR lambs ($P<0.001$): 0.352 vs. 0.061 g.100 g^{-1} FAME, 0.625 vs. 0.179 g.100 g^{-1} FAME and 0.252 vs. 0.079 g.100 g^{-1} FAME. Lanza et al. (2006) reported the significantly higher values of EPA, DPA and DHA in lambs fed ewe's milk (1.65, 2.34 and 1.25 g.100 g^{-1} FAME) than in AR lamb. Nevertheless, the authors found the values of EPA, DPA and DHA in lambs fed a milk replacer as high as 0.80, 1.18 and 0.53 g.100 g^{-1} FAME, respectively. Serra et al. (2009) reported the content of EPA, DPA and DHA in TR lambs slaughtered at live weight of 17 kg (similar weight to weight of lambs in the presented research) as follows: 0.90, 0.72 and 0.43 g.100 g^{-1} FAME. In comparison to AR lambs in the presented study, the higher values may be a result of fact that ewes and lambs in the experiment of Serra et al. (2009) were allowed to graze every day.

The fatty acid content as affected by lamb sex is shown in Table 1. Between male and female lambs, the only significant difference ($P<0.05$) was found in the content of arachidonic acid. This was 1.87 g.100 g^{-1} FAME in males and 1.35 g.100 g^{-1} FAME in females; being probably a result of differences between male and female vitality, voracity and metabolism. Vitality, voracity and metabolism may also be behind the different LA content between males and females (7.32 vs. 6.57 g.100 g^{-1} FAME), which tended to be significant ($P=0.0644$). The interaction between rearing system and lamb sex (Table 1) was found insignificant ($P>0.05$). Majority of studies is devoted to male lambs, whereas minority of studies deals with males and females simultaneously. Thus, limited comparisons can be done. The significant differences in the content of 3 out of 12 fatty acids were reported by Arsenos et al. (2006), who compared the fatty acid profiles between heavy male and female lambs of several breeds in Greece.

The content of some fatty acids grouped by type, and ratios and indexes important with respect to human health (Wood et al., 2003; Sinanoglou et al., 2013) are shown in Table 2. Lamb meat is considered to be a highly nutritious and easy digestible with a positive fatty acid composition (Milewski, 2006; Nuernberg et al., 2008). Some doubts about the consumption of red meat (including lamb meat) and its lipid composition arose due to the relatively high saturated fatty acid (SFA) content and the relatively low PUFA content (McAfee et al., 2010). As a difference to Lanza et al. (2006), the presented research did not reveal the significant difference in the content of SFA between TR and AR lambs (45.61 vs. 44.77 g.100 g^{-1} FAME). These values were higher than those reported by Lanza et al. (2006): 37.73 vs. 34.10 g.100 g^{-1} FAME. Also, the higher MUFA content was found in TR lambs than in AR lambs (42.50 vs. 43.26 g.100 g^{-1} FAME) when comparisons with study of Lanza et al. (2006) were done: 33.32 vs. 34.89 g.100g^{-1} FAME. The differences are probably a result of fact that lambs in the presented research were fed not only ewe's milk and milk replacer diet exclusively, but they were also allowed to access roughage and concentrate diets. The values of SFA, MUFA and PUFA content reported here were similar to values found by Napolitano et al. (2002), who applied similar diets. The higher PUFA content ($P<0.05$) in AR lambs than in TR lambs (12.72 vs. 11.13 g.100 g^{-1} FAME) may seem to be unexpected (Table 2). These findings, however, accorded with findings of Lanza et al. (2006) and Napolitano et al. (2002), who also reported the significantly higher PUFA content in AR lambs than in TR lambs (32.56 vs. 27.38 g.100 g^{-1} FAME and 13.59 vs. 11.62 %, respectively). The content of essencial fatty acids was also significantly higher in AR lambs ($P<0.001$). This is probably due to fact that AR lambs had the significantly ($P<0.001$) higher content of LA (9.07 vs. 4.81 g.100g^{-1} FAME) and ratio of LA/ALA (39.11 vs. 6.80). In addition, the ratio of n-6 PUFA/n-3 PUFA was significantly higher in AR lambs than in TR lambs: 14.56 vs. 3.25 ($P<0.001$). Although this ratio in AR lambs was higher than its recommended value (max 4:1), it is in accordance with findings of Napolitano et al. (2002) and Lanza et al. (2006), who reported n-6 PUFA/n-3 PUFA ratios in AR and TR lambs as follows: 9.54 vs. 1.95 and 7.95 vs. 0.59, respectively. The undesirable n-6 PUFA/n-3 PUFA ratio in AR lambs resulted from a significantly higher content of n-6 PUFA than n-3 PUFA in IMT ($P<0.001$) due to the feed ration with a high content of coconut and palmic oil, which are known for a high content of n-6 PUFA. At present, it is generally accepted that the composition of fatty acids in suckling lamb's tissues depends on the fatty acid profiles in ewe's milk; the milk composition being consistently affected by ewe's nutrition (Velasco et al., 2001).

With MUFA, it is important to emphasise that meat of suckling lambs comprises branched chain fatty acids (Sinanoglou et al., 2013). These (mostly *iso* fatty acids) mainly occur in milk lipids. The significantly higher ($P<0.001$) content of branched chain fatty acids (1.95 vs. 0.45 g.100 g^{-1} FAME) was found in TR lambs than in AR lambs (Table 2). Branched chain fatty acids are useful indicators of rumen activity (Serra et al., 2009). Their content in lamb meat increases with an increase of carcass weight. The content of branched chain fatty acids in TR lambs found in this study (1.95 g.100 g^{-1} FAME) was higher than that reported by Serra et al. (2009) for suckling lambs of three different carcass weights (11, 14 and 17 kg): 0.47, 0.63 and 0.76 g.100 g^{-1} FAME, respectively. The lower content of branched chain fatty acids in AR lambs (0.45 g.100g^{-1} FAME) seems to be an evidence of lower rumen activity.

The nutrition value of lipids is assessed on a basis of various ratios and indexes (Orellano et al., 2009; Sinanoglou et. al., 2013): MUFA/SFA (M/S) ratio, PUFA/SFA (P/S) ratio, n-6/n-3 PUFA ratio, hypocholesterolaemic fatty

acids/hypercholesterolaemic fatty acids (h/H) ratio, hypercholesterolaemic index (HI), atherogenic index (AI), thrombogenic index (TI), cholesterol index (CI) etc. The ratios and indexes as affected by rearing system are shown in Table 2. The ratio of PUFA/SFA was found lower (0.287 vs. 0.247 in AR and TR lambs, respectively) than values being recommended as health promoting values: above 0.7 according to Raes et al. (2004) and Lanza et al. (2006), and 0.45 according to Williams (2000). The higher M/S and P/S ratios are reported, the better balance of fatty acids in tissues was found. The lower ratio of P/S (when comparing with its recommended value) was reported by Napolitano et al. (2002): 0.25 in lambs fed ewe's milk vs. 0.31 in AR lambs. Sinanoglou et al. (2013) found the ratios of P/S ranging from 0.37 to 0.49 in lambs of various breeds in Greece. Lanza et al. (2006) found a ratio of P/S equal to 0.73 in light lambs fed ewe's milk and equal to 0.96 in lambs on a milk replacer diet. This was probably a result of the remarkable high content of PUFA (27.38 vs. 32.96 g.100g^{-1} FAME). Díaz et al. (2005) reported the following ratios of P/S in dependence on lamb's origin: 0.38 (Spanish light lambs), 0.20 (German light lambs), 0.19 (British light lambs) and 0.21 (Uruguayan light and heavy lambs). According to Williams (2000), a ratio of n-6 PUFA/n-3 PUFA plays a significant role in the risk of atherosclerosis. The recommended value of this ratio is 4:1 at maximum (Raes et al., 2004). In a diet of various human populations, the ratio of 10:1 may be observed (Simopoulos, 2002). The low ratio of n-6 PUFA/n-3 PUFA reduces the risk of many chronical diseases that occur in some European and North American populatios (Simopoulos, 2002). In this study, the desirable ratio of n-6 PUFA/n-3 PUFA was found in TR lambs (3.25:1); the ratio highly exceeded the recommended value in AR lambs (14.56:1). The h/H index may be useful when assessing the cholesterolaemic effect of lipids. Similarly to Raes et al. (2003) and Sinanoglou et al. (2013), no significant difference between AR and TR lambs was found (Table 2). Since lipid deposits differ among breeds, this ratio seems to be mainly affected by genetic factors. Sinanoglou et al. (2013), who compared suckling lambs of 4 breeds, found h/H indexes ranging between 1.88 and 2.36. Table 2 shows findings about AI and TI. The non-significant difference in AI between AR and TR lambs was found (0.906 vs. 0.868). The significant difference ($P<0.05$) in TI between AR and TR lambs was found (1.44 vs. 1.31). According to Sinanoglou et al. (2013), the appropriate values of AI and TI for a healthy diet are under 1.0. The AI values found in this study accorded with this recommended value and were close to findings of Vacca et al. (2008), who also found AI equal to 1.0 in suckling Sarda purebred and crossbred lambs. They were lower than Oriani et al. (2005) found in Merino lambs (1.35), but were higher than Sinanoglou et al. (2013) found in IMT of suckling lambs of 4 breeds in Greece (0.55 to 0.73). They indicate that meat of Slovak lambs is healthy food with a favourable fatty acid composition and cardiovascular disease prevention. The TI values were higher than the recommended value; the less favorable TI was found in AR lambs. Except for Oriani et al. (2005), who reported TI equal to 1.69, the lower values of TI (1.1 and 0.83 to 1.21) were found (Vacca et al., 2008; Sinanoglou et al., 2013) in IMT of suckling lambs.

The content of DFA, firstly applied by Díaz et al. (2002), is also useful when assessing quality of lamb meat. In the presented research, the content of DFA was 65.36 vs. 67.06 g.100 g^{-1} FAME in IMT of AR and TR lambs ($P=0.1053$). Díaz et al. (2002) found the content of DFA 63.05 and 59.05 g/100 g FAME for lambs kept on pasture and in sheepfold, respectively. The authors investigated the content of DFA also in dependence on lamb weight and found values of 59.23 vs. 62.86 g.100 g^{-1} FAME in light and heavy lambs, respectively. When comparing the content of DFA

with that reported by Díaz et al. (2002), finding of this study indicate that Slovak lambs are of good quality meat.

Table 2 also shows findings about fatty acids grouped by type, and important ratios and indexes in dependence of lamb sex. No significant differences between males and females were found (P>0.05). The differences were the highest in PUFA, essential fatty acids and *n-6* PUFA. Similarly to the higher content of ALA found in males, the different male and female lamb feeding behaviour and metabolism may be behind this phenomenon. Arsenos et al. (2006) found the significant (P<0.05) effect of lamb sex in 1 (PUFA) of 4 fatty acid groups (SFA, UFA, MUFA, PUFA).

Conclusions

The complex assessment of 40 light lambs from artificial and traditional rearing system was done. In general, the less favourable quality, assessed on a basis of fatty acid profiles in intramuscular fat, was found in artificially reared lambs. This is true mainly with health promoting fatty acids (CLA, EPA, DHA), and the content and ratios of saturated, monounsaturated and polysaturated fatty acids. Artificially reared lambs were also found to have the undesirable n-6 PUFA/n-3 PUFA ratio.

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References

Ackman, R. G. (2002) The gas chromatograph in practical analyses of common and uncommon fatty acids for the 21st century. Analytica Chimica Acta, 465, 175-192

Arsenos, G., Kufidis, D., Zygoyiannis, D., Katsaounis, N., Stamataris, C. (2006) Fatty acid composition of lambs of indigenous dairy Greek breeds of sheep as affected by post-weaning nutritional management and weight at slaughter. Meat Science, 73, 55-65

Bas, P., Morand-Fehr, P. (2000) Effect of nutritional factors on fatty acid composition of lamb fat deposits. Livestock Production Science, 64, 61-79

Carrasco, S., Ripoll, G., Sanz, A., Álvarez-Rodríguez, J., Panea, B., Revilla, R., Joy, M. (2009) Effect of feeding system on growth and carcass characteristics of Churra Tensina light lambs. Livestock Science, 121, 56-63

Cruz-Hernandez, C., Kramer, J.K.G., Kennelly, J.J., Glimm, D.R., Sorensen, B.M., Okine, E.K., Goonewardene, L.A., Weselake, R.J. (2007) Evaluating the conjugated linoleic acid and trans 18:1 isomers in milk fat of dairy cows fed increasing amounts of sunflower oil and a constant level of fish oil. Journal of Dairy Science, 90, 3786-3801

Díaz, M.T., Velasco, S., Canegue, V., Lauzurica, S., Ruiz de Huidobro, F., Pérez, C., González, J., Manzanarez, C. (2002) Use of concentrate or pasture for fattening lambs and its effect on carcass and meat quality. Small Ruminant Research, 43, 257-268

Díaz, M.T., Álvarez, I., De la Fuente, J., Sanudo, C., Campo, M.M., Oliver, M.A., Font i Furnols, M., Montossi, F., San Julián, R., Nute, G.R., Caneque, V. (2005) Fatty acid composition of meat from typical lamb production systems in Spain, United Kingdom, Germany and Uruguay. Meat Science, 71, 256-263

Jerónimo, E., Alves, S, P., Prates, J.A.M., Santos-Silva, J., Bessa, R.J.B. (2009) Effect of dietary replacement of sunflower oil with linseed oil on intramuscular fatty acids of lamb meat. Meat Science, 83, 499-505

Juárez, M., Horcada, A., Alcalde, M.J., Valera, M., Mullen, A.M., Molina, A. (2008) Estimation of factors influencing fatty acid profiles in light lambs. Meat Science, 79, 203-210

Juárez, M., Horcada, A., Alcalde, M.J., Valera, M., Polvillo, O., Molina, A. (2009) Meat and fat quality of unweaned lambs as affected by slaughter weight and breed. Meat Science, 83, 308-313

Lanza, M., Bella, M., Priolo, A., Barbagallo, D., Galofaro, V., Landi, C., Pennisi, P. (2006) Lamb meat quality as affected by a natural or artificial milk feeding regime. Meat Science, 73, 313-318

Martinez-Cerezo, S., Sanudo, C., Panea, B., Medel, I., Delfa, R., Sierra, I., Beltran, J.A., Cepero, R., Olleta, J.L. (2005) Breed, slaughter weight and ageing time effects on physico-chemical characteristics of lamb meat. Meat Science, 69, 325-333

Margetín, M., Michalík, Š. (1998) Sheep and goat husbandry in the Slovak Republic. In: S., Kukovics, ed. (1998) Sheep and Goat Production in Central and Eastern European countries. REU Technical Series, 50, FAO Rome, p.p. 250-264

Margetín, M. (2007) Spôsoby odchovu jahniat dojných oviec. Chov oviec a kôz, 27 (1), 8-10

Margetín, M., Margetínová, J., Gálisová, M., Čapistrák, A., Špánik, J. (2009) Intenzita rastu jahniat odchovaných pomocou dôsledného škôlkovania a jahniat z umelého odchovu. Slovenský chov, 14 (11), 27-29

Margetín, M., Debrecéni, O., Čapistrák, A., Špánik, J., Apolen, D., Gálisová, M., Oravcová, M. (2010) Behaviour and growth intensity of dairy sheep lambs raised in nurseries. Slovak Journal of Animal Science, 43, 88-94

McAfee, A.J., McSorley, E.M., Cuskelly, G.J., Moss, B.W., Wallace, J.M.W., Bonham, M.P., Fearon, A.M. (2010) Red meat consumption: An overview of the risks and benefits. Meat Science, 84, 1-13

Milewski, S. (2006) Health-promoting properties of sheep products. Medycyna Weterynaryjna, 62, 516-519

Napolitano, F., Cifuni, G.F., Pacelli, C., Riviezzi, A.M., Girolami, A. (2002) Effect of artificial rearing on lamb welfare and meat quality. Meat Science, 60, 307-315

Nuernberg,K., Fischer, A., Nuernberg, G., Ender, K., Dannenberger, D. (2008) Meat quality and fatty acid composition of lipids in muscle and fatty tissue of Skudde lambs fed grass versus concentrate. Small Ruminant Research, 74, 279-283

Orellano, C., Pepa, F., Garcva, A., Perea, J., Martos, J., Domenech, V., Acero, R. (2009) Carcass characteristics, fatty acid composition, and meat quality of Criollo, Argentino and Braford steers raised on forage in a semitropical region of Argentina. Meat Science, 81, 57–64

Oriani, G., Maiorano, G., Filetti, F., Di Cesare, C., Manchisi, A., Salvatori, G. (2005) Effect of age on fatty acid composition of Italian Merino suckling lambs. Meat Science, 71, 557-562

Osorio, M.T., Zumalacárregui, J.M., Figueira, A., Mateo, J. (2007) Fatty acid composition in subcutaneous, intermuscular and intramuscular fat deposits of suckling lamb meat: effect of milk source. Small Ruminant Research, 73, 127-134

Raes, K., Balcaen, A., Dirinck, P., De Winne, A., Claeys, E., Demeyer, D., De Smet, S. (2003) Meat quality, fatty acid composition and flavour in Belgian retail beef. Meat Science, 65, 1237-1246

Raes, K., De Smet, S., Demeyer, D. (2004) Effect of dietary fatty acids on incorporation of long chain polyunsaturated fatty acids and conjugated linoleic acid in lamb, beef and pork meat: a review. Animal Feed Science and Technology, 113, 199-221

Santos-Silva, J., Bessa, R.J.B., Santos-Silva, F. (2002) Effect of genotype, feeding system and slaughter weight on the quality of light lambs. II. Fatty acid composition of meat. Livestock Production Science, 77, 187-194

Sanudo, C., Alfonso, M., Sánchez, A., Delfa, R., Teixeira, A. (2000) Carcass and meat quality in light lambs from different fat classes in the EU carcass classification system. Meat Science, 56, 89-94

SAS Institute Inc. (2009) *SAS/STAT ® 9.2User's Guide, Second Edition*, Cary, NC USA

Scerra, M., Caparra, P., Foti, F., Galafaro, V., Sinatra, M.C., Scerra, V. (2007) Influence of ewe feeding systems on fatty acid composition of suckling lambs. Meat Science, 76, 390-394

Serra, A., Mele, M., La Comba, F., Conte, G., Buccioni, A., Secchiari, P. (2009) Conjugated Linoleic Acid (CLA) content of meat from three muscles of Massese suckling lambs slaughtered at different weights. Meat Science, 81, 396-404

Sinanoglou, V.J., Batrinou, A., Mantis, F., Bizelis, I., Miniadis-Meimaroglou, S. (2013) Lipid quality indices: Differentiation of suckling lamb and kid breeds reared by traditional sheep farming. Small Ruminant Research, 113, 1-10

Simopoulos, A.P. (2002) The importance of the ratio of omega-6/omega-3 essential fatty acids. Dossier: polyunsaturated fatty acids in biology and diseases. Biomedicine & Pharmacotherapy, 56, 365–379

Tejeda, J.F., Peña, R.E., Andrés, A.I. (2008) Effect of live weight and sex on physico-chemical and sensorial characteristics of Merino lamb meat. Meat Science, 80, 1061-1067

Ulbricht, T.L.V., Southgate, D.A.T. (1991) Coronary heart disease seven dietary factors. The Lancet, 338, 985-992

Vacca, G.M., Carcangiu, V., Dettori, M.L., Pazzola, M., Mura, M.C., Luridiana, S., Tilloca, G. (2008) Productive performance and meat quality of Mouflon x Sarda and Sarda x Sarda suckling lambs. Meat Science, 80, 326-334

Vasta, V., Nudda, A., Cannas, A., Lanza, M., Priolo, A. (2008) Alternative feed resources and their effects on the quality of meat and milk from small ruminants. Animal Feed Science and Technology, 147, 223-246

Velasco, S., Caneque, V., Lauzurica, S., Pérez, C., Lauzurica, S., Díaz, M.T., Huidobro, F., et al. (2001) Fatty acid composition of adipose depots of suckling lambs raised under different production systems. Meat Science, 59, 325-333

Velasco, S., Caneque, V., Lauzurica, S., Pérez, C., Huidobro, F. (2004) Effect of different feeds on meat quality and fatty acid composition of lambs fattened at pasture. Meat Science, 66, 457-465

Williams, C.M. (2000) Dietary fatty acids and human health. Annales de Zootechnie, 49, 165-180

Wood, J.D., Richardson, R.I., Nute, G.R., Fischer, A.V., Campo, M.M., Kasapidou, E., Sheard, P.R., Enser, M. (2003) Effects of fatty acids on meat quality: a review. Meat Science, 66, 21-32

Zygoyiannis, D., Stamataris, C., Catsaounis, N. (1985) The melting point, iodine value, fatty acid composition and softness index of carcass fat in three different breeds of suckled lambs. Journal of Agricultural Science, 104, 361-365

Table 1. Composition of fatty acids in intramuscular fat (g.100g^{-1} FAME)

Fatty acids	Lambs rearing		P	Lambs sex		P	Interaction (P)	SEM	R^2
	AR	TR		Male	Female				
C12:0 (lauric)	1.36	0.473	<0.0001	0.938	0.892	0.7369	0.4121	0.415	0.543
C14:0 (myristic)	5.21	5.31	0.7955	5.29	5.23	0.8759	0.2464	1.133	0.048
C16:0 (palmitic)	26.68	22.97	<0.0001	24.55	25.11	0.3260	0.347	6.875	0.558
C16:1 *cis9* (palmitooleic)	0.346	0.512	<0.0001	0.421	0.437	0.5109	0.2201	0.072	0.577
C17:0 (margarinic)	0.406	1.145	<0.0001	0.765	0.786	0.7659	0.5792	0.207	0.775
C18:0 (stearic)	10.14	12.68	<0.0001	11.35	11.46	0.8286	0.7382	1.523	0.427
C 18:1 *trans9* (elaidic)	0.131	0.240	<0.0001	0.182	0.189	0.3956	0.2296	0.023	0.852
C18:1 *cis9* (OA)	37.87	35.44	<0.0019	36.38	36.92	0.4587	0.0841	2.176	0.361
C18:1 *trans11* (TVA)	0.111	0.955	<0.0001	0.519	0.548	0.3935	0.3134	0.101	0.950
C18:2 n-6 (LA)	9.07	4.81	<0.0001	7.32	6.57	0.0644	0.9138	1.183	0.786
C18:3 n-6 (GLA)	0.076	0.053	<0.0001	0.067	0.063	0.4002	0.7764	0.015	0.404
C18:3 n-3 (ALA)	0.251	0.715	<0.0001	0.497	0.670	0.4297	0.2027	0.102	0.859
C18:2 *cis9.trans11* (RA)	0.148	0.672	<0.0001	0.409	0.411	0.9638	0.5439	0.130	0.823
C20:4 n-6 (AA)	1.56	1.66	0.6628	1.87	1.35	0.0328	0.7995	0.703	0.125
C20:5 n-3 (EPA)	0.061	0.352	<0.0001	0.216	0.196	0.5859	0.4319	0.111	0.674
C22:5 n-3 (DPA)	0.179	0.625	<0.0001	0.438	0.365	0.2106	0.4549	0.173	0.668
C22:6 n-3 (DHA)	0.079	0.252	<0.0002	0.162	0.169	0.8668	0.2239	0.124	0.406

AR: artifical rearing; TR: traditional rearing

Table 2. Compostion of important fatty acids grouped by type (g.100 g^{-1} FAME), ratios and indexes of fatty acids

Fatty acids/Ratios/Indexes	Lambs rearing		P	Lambs sex		P	Interaction (P)	SEM	R^2
	AR	TR		Male	Female				
SFA	44.77	45.61	0.4061	44.92	45.47	0.5883	0.3310	3.011	0.069
MUFA	42.50	43.26	0.3136	42.48	43.29	0.2876	0.0674	2.247	0.121
PUFA	12.72	11.13	0.0320	12.60	11.25	0.0674	0.5994	2.158	0.192
Trans MUFA	1.35	3.85	<0.0001	2.58	2.62	0.6489	0.3048	0.291	0.952
Cis MUFA	41.04	39.67	0.0574	39.99	40.71	0.3111	0.0823	2.099	0.236
BCFA (iso. anteiso)	0.45	1.95	<0.0001	1.21	1.19	0.8614	0.8436	0.263	0.901
Esencial FA (LA+ALA)[1]	9.33	5.53	<0.0001	7.81	7.04	0.0558	0.8262	1.183	0.746
LC n-6 PUFA	1.91	1.85	0.8104	2.07	1.69	0.1157	0.6536	0.721	0.073
LC n-3 PUFA	0.58	1.37	<0.0001	1.05	0.91	0.3277	0.4366	0.422	0.521
n-6 PUFA	10.98	6.67	<0.0001	9.39	8.26	0.0564	0.7945	1.735	0.642
n-3 PUFA	0.84	2.08	<0.0001	1.54	1.38	0.3121	0.3474	0.489	0.667
CLA	0.193	0.749	<0.0001	0.472	0.470	0.9688	0.5036	0.139	0.822
PUFA / SFA	0.287	0.247	0.0672	0.284	0.249	0.1014	0.7982	0.063	0.153
∑ n-6 PUFA/∑ n-3 PUFA	14.56	3.25	<0.0001	8.70	9.10	0.7214	0.6425	3.374	0.753
C18:2 n-6 / C18:3 n-3 (LA/ALA)	39.11	6.80	<0.0001	23.47	22.45	0.6758	0.8348	7.298	0.846
LC n-6 PUFA / LC n-3 PUFA	3.47	1.35	<0.0001	2.41	2.41	0.9983	0.5536	0.504	0.826
AI (atherogenic index)	0.906	0.868	0.4933	0.882	0.892	0.8482	0.2003	0.165	0.049
TI (thrombogenic index)	1.44	1.31	0.0346	1.35	1.40	0.4140	0.4381	0.175	0.133
h/H index	1.55	1.57	0.8069	1.59	1.53	0.4411	0.3888	0.234	0.037
DFA (desirable fatty acids)	65.36	67.06	0.1053	66.43	66.00	0.6736	0.2671	3.067	0.086

AR: artifical rearing; TR: traditional rearing