

The fatty acid composition of *longissimus lumborum* muscle of suckling and early-weaned dual-purpose wool/meat lambs

Aurelia Radzik-Rant, Witold Rant, Agnieszka Rozbicka-Wieczorek and Ewa Kuźnicka

Department of Animal Breeding, Faculty of Animal Science, Warsaw University of Life Sciences, Warsaw, Poland

Abstract

Twenty-four dual purpose (wool/meat) suckling and early weaned ram lambs were used to study the fatty acid profile in intramuscular fat of *longissimus lumborum* muscle and lipid oxidation in blood serum. At 60 days of age 12 rams were slaughtered as suckling lambs. The other 12 early weaned and fed according to standards by grass hay and concentrate, and slaughtered at 90 days of age. Suckling lambs had more polyunsaturated fatty acids ($P \leq 0.01$) than early-weaned lambs. Younger lambs obtained also higher values of n-3 fatty acids ($P \leq 0.01$) and lower n-6/n-3 ratio ($P \leq 0.01$) appropriate in relation to their contribution to human health. Muscle tissue of early-weaned lambs compared to suckling group was characterised by significantly higher c9,t11C18:2 content ($P \leq 0.01$), which is desirable in human diet with regard to its peculiarities. The higher amount ($P \leq 0.01$) of vaccenic acid, which is the substrate for rumenic acid formation, has been observed in early-weaned lambs also.

Keywords: suckling lambs, early-weaned lambs, fatty acids

Introduction

The fatty acid composition plays remarkable role in the definition of quality and nutritional value of meat for human consumption (Williams 2000). Lipid peroxidation is one of the major causes of quality deterioration in raw and cooked meat products. The oxidation of lipids results in the production of compounds, which affect the flavour and colour of meat. The toxicity, mutagenicity and carcinogenicity of malonaldehyde, which is formed during meat oxidation is also known (Pearson *et al.* 1983, Wood & Enser 1997).

The fatty acid composition in the diet is very important in relation to consumer health. An unbeneficial fatty acid composition of dietary lipids (saturated fatty acid, n-6 unsaturated fatty acid) was demonstrated to increase the risk to contract coronary heart disease (Kritchevsky 1998, Hu *et al.* 1999). The polyunsaturated fatty acids (PUFAs), particularly n-3 PUFAs exert beneficial effects against cardiovascular and tumour diseases, inflammatory and immune disorders, and neurological dysfunctions (Fernandez & Venkatraman 1993, Burns & Spector 1994, Calder 1998). The conjugated linoleic acids (e.g. c9,t11 C18:2) have the same profitable effect on human health (Khanal & Dihman 2004). Among ruminant-origin meat, lamb meat can be characterised by comparatively high amounts of beneficial conjugated linoleic acids (Schmid *et al.* 2006).

Different factors influence lambs fatty acid profile. It has been shown that fat composition of lamb's tissues may be modified by diet and animal production system (Diaz *et al.* 2002, Wachira *et al.* 2002, Rhee *et al.* 2003). Breed and body weight/age at slaughter can also influence the fatty acids profile of lamb's meat (Cifuni *et al.* 2000, Marino *et al.* 2008).

Depending on production system and consumer preferences, lambs can be slaughtered as suckling in light live weight or after weaning and fattening at older age and higher body weight. The fat composition of suckling lambs is mainly related to the fat composition of the milk they consume. The suckling lambs have not yet developed a functional rumen with its corresponding microorganisms, for that reason dietary compounds undergo less intensive ruminal degradation than in weaned lambs (Diaz *et al.* 2003). The changes in fat metabolism that occur with an increase of age affect nutritional quality of lamb's meat.

The aim of the present study was indication the meat quality and its health value of suckling and early-weaned lambs, on the ground of fatty acid profile in *longissimus lumborum* muscle.

Material and methods

Animal treatments

The experiment has been conducted on dual wool/meat purpose lambs of Polish Lowland sheep. This strain of sheep with good body conformation and meat performance, characterise by high prolificacy (175 %), is reared in central part of Poland and mainly used to slaughter lambs production.

Randomly assigned, 24 single born ram lambs were used in this trial. All animals remained with their dams until two months of age.

The ewes received grass hay (3.9 MJ/kg dry matter [DM], 11.8 % crude protein [CP]/kg DM, 29.1 % crude fibre [CF]/kg DM, 0.94 % ether extract [EE]/kg DM) and concentrate (7.02 MJ/kg DM, 18 % CP/kg DM, 2.85 % EE/kg DM) containing: oat meal (31 %), wheat meal (23 %), wheat bran (15 %), rape meal (30 %), mineral mixture (1 %).

The lambs from two weeks of age received *ad libitum* grass hay and concentrate (7.1 MJ/kg DM, 15.1 % CP/kg DM, 2.68 EE/kg DM) containing: oat meal (31 %), rape meal (16 %), wheat meal (31 %), wheat bran (21 %), mineral mixture (1 %), as well as maternal milk.

At 60 days of age 12 lambs were slaughtered. The other 12 ram lambs weaned and fed according to standards by grass hay and concentrate through the next month. At the age of 90 days lambs were slaughtered. All the animals were individually weighed every two-week interval, and average daily gains were calculated.

Before slaughter lambs were fasted for 12 h and weighed. Then, taken to an abattoir and slaughtered according to standard commercial procedures. Carcasses were chilled at 4 °C for 24 h. On the right halves of the carcasses, the samples of *longissimus lumborum* muscle were taken, vacuum packed and frozen at –20 °C until being used for chemical analysis.

The milk samples (50 ml) were collected from ewes at 2th, 4th and 8th week of lactation and stored at 4 °C for analysis.

The blood for analysis of lipid oxidation was collected from jugular vein of lambs before slaughter. Serum was stored at –20 °C before use.

Analytical procedures

Fatty acid analysis (meat/milk)

Total lipids in lamb's muscle were extracted according to Folch *et al.* (1957). Fatty acid methyl esters were prepared according to method given by Kramer *et al.* (1997). Fatty acid composition of lipids was performed by gas-chromatograph analysis using Hewlett Packard GC 5890 instrument (Hewlett-Packard Company, Palo Alto, CA, USA) equipped with a fused-silica capillary column DB-23 (length 60 m, internal diameter 0.25 mm, film thickness 0.25 mm). Operating conditions were: helium flow 1.2 ml/min; a FID detector at 240 °C. The temperature programme of column was: 1 min at 130 °C, an increase to 170 °C by +10 °C/min, to 215 °C by +2.5 °C/min, to 230 °C by +20 °C/min. The fatty acids and fatty acid isomers were identified and quantified via following external FAME standards (Sigma-Aldrich Poland, Poznan, Poland): 18917, 18919, octadecadienoic acid, conjugated methyl ester 0-5632. Results are expressed in g/100 fat.

Lipids of milk were extracted using Röse-Gottlieb method (AOAC 1990). Gas chromatograph analysis was performed as described for meat, although temperature programme for the column was different: 130 °C (1 min), to 210 °C by +10 °C/min, to 230 °C by +2.5 °C. Identification of fatty acids was performed as described for meat. The fatty acids composition of ewe's milk and concentrate are reported in Table 1 and expressed in g/100g fat.

Table 1
Fatty acid composition (g/100g fat) of the feeds consumed by lambs

Fatty acids	Ewe's milk at 2nd week of lactation	Ewe's milk at 4th week of lactation	Ewe's milk at 8th week of lactation	Concentrate
C4:0	2.91	2.69	2.59	-
C6:0	2.07	1.70	1.92	-
C8:0	1.37	1.28	1.29	-
C10:0	6.29	5.49	5.57	-
C12:0	3.65	3.73	3.76	0.19
C14:0	8.49	8.63	8.80	0.19
C16:0	22.43	23.16	23.04	14.63
C17:0	0.93	0.92	0.95	0.10
C18:0	11.2	12.14	11.63	1.43
C20:0	-	-	-	0.19
C14:1	1.05	1.05	1.07	-
C16:1	0.30	0.32	0.36	0.29
C18:1c9	22.47	22.13	22.45	30.31
C18:1t11	2.14	1.95	1.98	-
C18:2 n-6	2.54	2.45	2.40	41.30
C18:2 c9,t11	0.44	0.49	0.48	-
C18:3 n-3	0.66	0.70	0.70	3.35
C20:4 n-6	0.18	0.20	0.19	-
C20:5 n-3	0.11	0.11	0.11	-
C22:6 n-3	0.07	0.06	0.07	-

Fodder analysis

Chemical composition and nutritional value of fodder were analysed according to AOAC standard methods (1990). Lipids from representative sample of concentrate were extracted using the method Folch *et al.* (1957). Methyl esters were prepared according to the Polish

standard PN-EN ISO 5509 (2001) using boron trifluoride. Gas chromatograph analysis of fatty acid methyl esters was performed in accordance with PN-EN ISO 5508 (1996) (capillary column BXP 70, length 60m, internal diameter 0.22 mm, film thickness 0.25 mm).

Lipid peroxidation analysis

Lipid oxidation in serum was assessed by measuring thiobarbituric acid reactive substances (TBARS). The thiobarbituric acid test was performed according to Nair & Turner (1984). Lipid oxidation is expressed in nmol TBARS/ml serum.

Statistical analysis

Least squares procedures were used to analyse lipid content and fatty acid composition based on a linear model that included the effect of animal's treatment (suckling and early-weaned lambs).

The effects were tested against residual mean-squares to determine level of significance. Computations were performed using SPSS 14.0 software (SPSS Inc., Chicago, IL, USA).

Results and discussion

The suckling lambs slaughtered at 60 days of age did not exceed body weight required for light lambs (17-22 kg) in Poland. The average body weight of early-weaned lambs slaughtered at 90 days of age was over 6 kg higher (Table 2).

Table 2
Growth rate of suckling and early-weaned lambs

	Suckling lambs	Early-weaned lambs	Standard error	Statistical significance
Birth body weight, kg	4.97	5.41	0.24	ns
Body weight at 60 days, kg	21.67	20.86	0.82	ns
Daily gain between 1st and 60th day, g/day	297.11	284.88	17.46	ns
Body weight at 90 days, kg	-	27.88	1.00	
Daily gain between 60th and 90th day, g/day	-	210.27	12.61	

ns: not significant

The differences of total lipids content were not statistically significant in both groups of lambs (Table 3). The greater ages and weights are not always associated with higher intramuscular fat content, what has been also reported by Oriani *et al.* (2005) and Marino *et al.* (2008). The lack of markedly increase of total lipids in older lambs may be due to growth rate decrease after weaning (Table 2).

The fatty acid composition in intramuscular fat of suckling and early-weaned lambs is reported in Table 3. Meat from *longissimus lumborum* muscle of early weaned lambs had a higher content ($P \leq 0.01$) of C16:0 and C15:0, and lower content ($P \leq 0.01$) of C12:0, C14:0 than suckling lambs. The higher amount of palmitic acid (C16:0) in meat of older lambs has been also reported by Cifuni *et al.* (2000). The higher C12:0 and C14:0 content could be due to their appreciable amount in ewe's milk (Table 1), which suckling lambs used until slaughter. The

greater value of C15:0 in early-weaned group of lambs could be related with development of ruminal microflora, as those odd-numbered carbon atoms fatty acids are originated from bacterial lipids (Jenkins 1993).

Table 3

Total lipids (g/100 g muscle tissue (fresh matter)) and fatty acid composition (g/100 g fat) of *longissimus lumborum* of suckling and early-weaned lambs

	Suckling lambs	Early-weaned lambs	Standard error	Statistical significance
Total lipids	2.15	2.32	0.25	ns
C10:0	0.05	0.08	0.01	ns
C12:0	0.51	0.36	0.03	**
C14:0	4.35	3.80	0.12	**
C15:0	0.56	0.69	0.03	**
C16:0	22.30	23.71	0.28	**
C17:0	1.12	1.01	0.05	ns
C18:0	16.37	16.02	0.18	ns
C14:1	0.50	0.52	0.01	ns
C15:1	0.33	0.32	0.01	ns
C16:1	2.72	2.42	0.10	*
C17:1	0.75	0.52	0.04	**
C18:1 n-7	0.90	0.68	0.04	**
C18:1 n-9	31.74	31.42	0.33	ns
C18:1 t11 (TVA)	2.31	2.71	0.05	**
C20:1	0.11	0.15	0.01	**
C18:2 n-6	5.04	4.72	0.10	*
C18:2 c9,t11 (CLA)	0.36	0.59	0.02	**
C18:3 n-3	1.36	0.98	0.04	**
C20:3 n-3	0.17	0.21	0.01	**
C20:4 n-6	1.11	1.09	0.04	ns
C20:5 n-3 (EPA)	0.54	0.42	0.02	**
C22:5 n-3 (DPA)	0.51	0.36	0.02	**
C22:6 n-3(DHA)	0.17	0.16	0.01	ns

ns: not significant, * $P \leq 0.05$, ** $P \leq 0.01$, TVA: *trans* vaccenic acid, CLA: conjugated linoleic acid, EPA: eicosapentaenoic acid, DPA: docosapentaenoic acid, DHA: docosahexaenoic acid

The highest amount from among monounsaturated fatty acids in intramuscular fat of suckling and early-weaned lambs was obtained for oleic acid (C18:1c9) (Table 3). However, the statistical differences between these groups of lambs have not been significant. The greater content of other monounsaturated fatty acids C16:1 ($P \leq 0.05$), C17:1 and C18:1 n-7 ($P \leq 0.01$) has been noted in younger lambs (Table 3). The monounsaturated fatty acids except it, that effectively reducing plasma cholesterol (Castelli 1993, Renner 1995), together with other fatty acids determines firmness/oiliness and oxidative stability of muscle, which affects juiciness, flavour and muscle colour (Wood *et al.* 2008).

The content of linolenic (C18:3), eicosapentaenoic (EPA), docosapentaenoic (DPA) fatty acids was higher ($P \leq .01$) in *longissimus lumborum* muscle of suckling lambs than early weaned, slaughtered at 90-days (Table 3). The similar results have been reported by Cifuni *et al.* (2000) in intramuscular fat of 45 and 90-day-old lambs, as well as Marino *et al.* (2008) in lambs slaughtered at 42 and 70 days of age.

In presented study, the source of long-chain fatty acids could be hay for C18:3 and concentrate for C18:2, given for lambs from two weeks of life. The higher content of these acids in suckling lambs could result from it, that they may not have the final ruminal microflora and dietary unsaturated fatty acids could be bacterially modified in less extend than in early weaned lambs and unchanged incorporated into tissues (Jenkins 1993, Wood *et al.* 2008). Linolenic acid, originated from dietary lipids, could allow the endogenous synthesis of long-chain PUFA by elongase and desaturase activities. C18:3 is a precursor of long-chain n-3 fatty acids such as EPA, DPA and DHA (White 1995).

The suckling lambs slaughtered at 60 days of age presented higher amount of unsaturated fatty acids ($P \leq 0.01$), especially PUFA ($P \leq 0.01$) and had better PUFA/saturated fatty acid ($P \leq 0.01$) ratio than early weaned lambs, slaughtered at older age (Table 4). This is in accordance with Nuernberg *et al.* (1998) hypothesis, that PUFA decrease with age.

Table 4

Fatty acid classes, relations and indexes (g/100g fat) of longissimus lumborum muscle and TBA-RS value (nmol/ml serum) in blood serum of suckling and early-weaned lambs

	Suckling lambs	Early-weaned lambs	Standard error	Significance
SFA	45.26	45.67	0.36	ns
MUFA	39.36	38.74	0.36	ns
PUFA	9.27	8.53	0.12	**
UFA	48.62	47.27	0.35	**
n-3	2.75	2.13	0.06	**
n-6	6.15	5.81	0.09	ns
UFA/SFA	1.08	1.04	0.02	ns
MUFA/SFA	0.87	0.85	0.01	ns
PUFA/SFA	0.20	0.19	0.00	**
n-6/n-3	2.24	2.75	0.07	**
C18:2 c9,t11 /C18:1 t11	0.17	0.24	0.01	**
TI	1.37	1.50	0.02	**
AI	0.56	0.60	0.01	ns
TBA-RS	1.51	1.32	0.06	ns

ns: not significant, * $P \leq 0.05$, ** $P \leq 0.01$, SFA: saturated fatty acids (C10:0+C12:0+C14:0+C15:0+C16:0+17:0+C18:0), MUFA: monounsaturated fatty acids (C14:1+C15:1+C16:1+C17:1+C18:1n-7+C18:1n-9+C20:1+C18:1t11 TVA), PUFA: polyunsaturated fatty acids (C18:2+C18:3+C20:3+C20:4+C20:5+C22:5+C22:6+C18:2c9,t11), UFA: unsaturated fatty acids (MUFA+PUFA), n-3: (C18:3+C20:3+C20:5+C22:5+C22:6), n-6: (C18:2+C20:4), TI: thrombogenic index (C14:0+C16:0+C18:0/ 0.5 SMUFA+0.5 SPUFA n-6+3 SPUFA n-3+n-3/n-6) (Ulbricht & Southgate 1991), AI: atherogenic index (C12:0+4 x C14:0+C16:0/ SMUFA+SPUFA n-6 and n-3) (Ulbricht & Southgate 1991)

Furthermore, C20:4 (AA) and C20:5 (EPA) are precursors to synthesis of eicosanoides like prostaglandines (PGE), prostacyclines (PGI), tromboxanes (TXA) and leucotrienes (LT). The PGE₂, PGI₂ TXA₂ and LT₄ are synthesised from n-6 fatty acid, whereas PGE₃, PGI₃ TXA₃ and LT₅ from n-3 fatty acid. The 2- and 4-series PGE/PGI/TXA/LT may contribute stimulation of proliferation processes, while 3- and 5-series PGE/PGI/TXA/LT have ability to inhibit of these processes (Gill & Valivety 1997, Grimble 1998) Thus, lowering n-6/n-3 ratio in human diet is very advisable. The amount of n-3 fatty acid was higher ($P \leq 0.01$) in meat tissue of suckling lambs, than in early weaned ones. Also n-6/n-3 ratio was lower ($P \leq 0.01$) and at the same better in *longissimus lumborum* muscle of suckling lambs (Table 4). This group of lambs, compared to early weaned was characterised by lower ($P \leq 0.01$) value of thrombogenic index

(Table 4). The better value of thrombogenic index for younger lambs (42 vs. 70 days) has been also reported by Marino *et al.* (2008).

The early-weaned lambs were characterised by higher c9,t11 C18:2 ($P<0.01$) content than suckling lambs (Table 3). This isomer could originate from the rumen, where is formed by biohydrogenation from alimentary PUFAs than directly incorporated to tissues, and from endogenous synthesis within tissues. In the tissues c9,t11 C18:2 is synthesised by $\Delta 9$ desaturase from vaccenic acid (Kay *et al.* 2002, Piperova *et al.* 2002, Khanal & Dihman 2004). The higher amount of vaccenic acid ($P\leq 0.01$) (Table 3) and higher C18:2 c9, t11 /C18:1 t11 ratio ($P\leq 0.01$) (Table 4), which expresses $\Delta 9$ desaturase activities, indicates enhanced *de novo* synthesis of conjugated linoleic acids in tissues of early weaned lambs, slaughtered at 90 days of age. The source of vaccenic acid, as a precursor for that synthesis, could be extended hydrogenation of C18 dietary fatty acids by better functioning rumen microflora in early-weaned lambs.

The higher proportion of c9,t11C18:2 is desirable in human diet. This isomer is the most biologically active conjugated linoleic acids isomer and has positive effect on preventing cancer, cardiovascular disease, diabetes and immune system (Pariza *et al.* 2001, Lock *et al.* 2004, O'Shea *et al.* 2004, Terpstra 2004).

The differences of TBARS value in serum of suckling and early-weaned lambs have not been statistically significant (Table 4). However, the TBARS value of serum tended to decrease in early-weaned lambs. The tendency to lower oxidation, estimated not in serum but in meat, has been observed for older lambs by Cifuni *et al.* (2000).

In conclusion, the observed differences of fatty acid profile in *longissimus lumborum* muscle of suckling and early-weaned lambs can be attributed to different physiological condition and digestive capabilities of the animals.

The not finally developed ruminal microflora of suckling lambs has made possible exogenous long-chain fatty acids incorporation into muscle lipids. These lambs had the higher value of n-3 fatty acids and lower n-6/n-3 ratio. Than at lambs with better functioning rumen microflora, the higher amount of vaccenic acid, which is essential to endogenous synthesis of rumenic acid, has been obtained. The content of c9,t11 C18:2 isomer was higher in early-weaned lambs.

Thus, the both groups of lambs were characterised by fatty acid profile compatible with good health and nutrition of consumers.

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Corresponding author:

Aurelia Radzik-Rant

email: aurelia_radzik_rant@sggw.pl

Department of Animal Breeding, Faculty of Animal Science, Warsaw University of Life Sciences, Ciszewskiego 8, 02-786 Warsaw, Poland
