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Effect of sex on meat chemical composition and fatty acid composition in suckling Pag sheep lambs

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ABSTRACT

The objective of this paper was to analyse the chemical composition of musculus longissimus dorsi (MLD), and the fatty acid composition of MLD, and kidney knob fat in Pag sheep suckling lambs carcasses, and to determine the effect of sex on those parameters. Although the Pag sheep belongs to a group of breeds of combined production traits, it is primarily bred for milk production, while the meat of suckling lambs is another important source of income. For this research muscle and fat samples were collected from 12 Pag sheep lamb carcasses (6 males and 6 females), slaughtered at the average age of 33 days. Although female lambs were heavier at slaughter, male lambs had heavier carcasses on average ($P<0.05$). The chemical composition of MLD was not affected by sex; meat from male and female lambs contained 25.82 % and 26.00 % of dry matter, 74.18 % and 74.00 % of moisture, 19.37 % and 19.13 % of protein, 5.25 % and 5.93 % of fat, and 1.17 % and 1.15 % of ash, respectively. Moreover, the sex had no significant effect on the fatty acid composition of MLD and kidney knob fat in Pag sheep lamb carcasses. However, the kidney knob fat of the experimental lambs contained more SFA than the muscle tissue, whilst the long-chain PUFA content of the former was concurrently lower than that of the latter. Total SFA, MUFA and PUFA contents in the MLD of Pag sheep lambs are in accordance with the results reported by other authors for the edible parts of the carcasses of Mediterranean suckling lambs, slaughtered at the age of 25 - 45 days.

Key words: Pag sheep lambs, longissimus dorsi, kidney knob fat, chemical composition, fatty acid

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Introduction

Fat and fatty acids, whether in adipose tissue or muscle, contribute importantly to various aspects of meat quality and are central to the nutritional value of meat (WOOD et al., 2008). Interest in the fatty acid composition of animal food, especially meat of various animal species in recent years has been subject of a great deal of research. This is because meat is seen to be a major source of fat in the diet, especially of saturated fatty acids, which have been implicated in diseases associated with modern life, especially in developed countries. The fatty acid composition of adipose tissue and muscle in pigs, sheep and cattle depends on the amount of fat in the carcass and muscles (WOOD et al., 2008). Meat quality is significantly influenced by fatty acid composition, because it influences the organoleptic characteristics, especially flavor (MELTON, 1990; WOOD and ENSER, 1997), and nutritional value of fat for human consumption (GRUNDY, 1987; WILLIAMS, 2000). The recommended ratio of polyunsaturated fatty acids (PUFA) to saturated fatty acids (SFA) should be above 0.4 (WOOD et al., 2003).

Many factors, such as breed, sex, live weight, environment, diet, degree of fatness, and their interactions have been shown to affect the fatty acid composition of lamb fat (DE SMET et al., 2004; WOOD et al., 2003). Diet has been shown to be one of the main factors influencing the fatty acid composition of lamb fat (WOOD et al., 2005). Thus, grain diets result in high concentrations of *n*-6 polyunsaturated fatty acids (PUFA), while grass diets increase muscle concentrations of *n*-3 PUFA (ENSER et al., 1998). In suckling lambs, the fatty acid composition of the intramuscular and subcutaneous fat was notably influenced by the fatty acid composition of the milk consumed (VELASCO et al., 2004).

The Pag sheep is a Croatian indigenous breed of local importance for the Island of Pag and the surrounding area, which is mainly bred for milk production. With an estimated population of around 30,000, Pag sheep comprises the largest island sheep population in Croatia. Although the main product of Pag sheep is milk, which is mainly processed into the famous Pag Island Cheese, their secondary product is meat from suckling lambs. In this production system, lambs are often an impediment for milking the ewes and they are slaughtered at a very young age from three to five weeks. Until that age the lambs are mainly fed their mothers' milk and very small quantities of pasture and hay, so high quality suckling lamb carcasses are produced. Such carcasses are characterised by high dressing percentage, light weight, small size and light pink meat colour (VNUČEC et al., 2014). The relevance and high edible quality of light lamb carcasses produced in European countries of the Mediterranean region have been studied by many authors (SAÑUDO et al., 2007; CARRASCO et al., 2009; JUÁREZ et al., 2009). However, to our knowledge, information on the meat quality traits and fatty acid composition of Pag sheep lambs has not been found to date. Therefore, the aim of this paper was to determine the chemical composition of the musculus longissimus dorsi (MLD) and the fatty acid composition

of the MLD intramuscular and kidney knob fat of Pag sheep suckling lamb carcasses, as well as to compare the results with those for some Mediterranean sheep breeds with the same production goal.

Materials and methods

The study was conducted on 12 (6 males and 6 females) randomly selected Pag sheep lambs kept in the same conditions from birth to slaughter. For detailed Pag sheep and lamb management, see VNUČEC et al. (2014). The lambs were slaughtered at an average age of 33 days in an authorized slaughterhouse. Prior to slaughter, the lambs were weighed in order to determine slaughter weight. After slaughter, carcass weight was recorded and representative samples of musculus longissimus dorsi (MLD) and kidney knob fat were collected from the right side of each carcass. Samples were vacuum packaged and stored at -20 °C until analysed for chemical composition and fatty acid profile.

Chemical composition and fatty acid analysis were performed at the University of Kaposvár, Faculty of Animal Science Institute of the Chemistry Department of Biochemistry & Food Chemistry in Hungary. After sample preparation, procedures described by AOAC (1995) were used to determine dry matter (DM, method ID 950.46), ash (method ID 920.153), Kjeldahl N (CP, method ID 981.10) and crude fat content (method ID 960.39) in the MLD samples.

The extracts of intramuscular and kidney knob lipids were analysed with a Chrompack CP 9000 gas chromatograph. Sample preparation and the gas chromatography conditions are explained below. A sample quantity, containing approximately 0.5-1.0 g fat was destructed with 8-20 cm^3 of hydrochloric acid (37 %) for 1 hour on a hot water bath. After cooling down, 7 cm^3 of ethanol was added. Lipids were extracted with 15 cm^3 diethyl ether and 15 cm^3 benzine (b.p. <60 °C), and the organic layers were combined. From a portion of this solution, containing approximately 150-200 mg fat, the solvents were removed at 80 °C under reduced pressure. Trans esterification: to the residue, 4 cm^3 of 0.5 M sodium hydroxide methanol solution was added and boiled until all the fat drops disappeared (approx. 5 min), then 4 cm^3 of 14 % boron trifluoride methanol solution was added, boiled for 3 min, finally 4 cm^3 of hexane dried on water-free sodium sulphate was added and boiled for 1 min, and the mixture was allowed to cool down. Saturated aqueous sodium chloride solution was added, and after separating, the organic layer was collected into a 4 cm^3 vial containing water-free sodium sulphate and it was directly examined by gas chromatography. The conditions of the gas chromatographic analyses were: Column: 100 m x 0.25 mm id, CS-Sil 88 (FAME) phase. Detector: FID 270 °C. Injector: splitter, 270 °C. Carrier gas: He, 235 kPa. Temperature program: 140 °C for 10 min; at 10 °C/min up to 235 °C; isotherm for 26 min. Injected volume: 0.5-2 μL.

Data were analysed with SAS Statistical Software (2008) using the T-test procedure to determine the effect of sex on chemical composition and fatty acid profile in Pag sheep lambs.

Results

The influence of sex on the slaughter and carcass weight and the basic chemical composition of the musculus longissimus dorsi (MLD) of Pag sheep lambs are reported in Table 1. Although the slaughter weights of both sexes were similar, male lambs had heavier carcasses ($P<0.05$). Female lambs had slightly more dry matter in the MLD muscle due to a higher proportion of fat compared to male lambs, but the difference was not statistically significant.

Table 1. Effect of sex on live weight, carcass weight and chemical composition of the longissimus dorsi muscle of Pag sheep lambs

Trait	Sex		Level of significance
	Male	Female	
Slaughter weight (kg)	10.16 ± 0.46	10.22 ± 0.18	NS
Carcass weight (kg)	6.37 ± 0.13	6.00 ± 0.09	*
Dry matter (%)	25.82 ± 0.60	26.00 ± 0.67	NS
Moisture (%)	74.18 ± 0.60	74.00 ± 0.67	NS
Protein (%)	19.37 ± 0.48	19.13 ± 0.18	NS
Fat (%)	5.25 ± 0.98	5.93 ± 0.72	NS
Ash (%)	1.17 ± 0.03	1.15 ± 0.02	NS

* $P<0.05$; NS - non significant

The effect of sex on the fatty acid composition of the longisimmus dorsi muscle of Pag sheep lambs is presented in Table 2. A higher proportion of myristic (C14:0), palmitoleic (C14:1), and eladic (C18:1n9t) fatty acid were found in females, while higher proportions of palmitic (C16:0) and stearic (C18:0) fatty acid were found in male lambs, although the differences were not significant. A statistically significant higher proportion of γ-linolenic (C18:3n6) fatty acid was found in males compared to female lambs. This difference should be taken with caution, because the determined values for γ-linoleic fatty acid were very low.

The aggregate values of SFA, MUFA, PUFA, UFA, *n*-3 and *n*-6, as well as PUFA/SFA, UFA/SFA and *n*-6/*n*-3 ratios of the MLD muscle are presented in Table 3. Ewe lambs had a slightly higher proportion of SFA and MUFA, and a higher UFA/SFA ratio compared to male lambs. On the other hand, male lambs had a higher proportion of PUFA, UFA, *n*-3 and *n*-6, and desirable rations of PUFA/SFA and *n*-6/*n*-3 fatty acids.

Table 2 . Effect of sex on longissimus dorsi muscle fatty acid composition in Pag sheep lambs

Fatty acid		Sex		Level of significance
Name	Symbol	Male	Female	
Capric	C10:0	0.21 ± 0.03	0.24 ± 0.03	NS
Undecanoic	C11:0	0.01 ± 0.00	0.01 ± 0.00	NS
Lauric	C12:0	0.60 ± 0.07	0.63 ± 0.05	NS
Trideccanoic	C13:0	0.04 ± 0.01	0.05 ± 0.00	NS
Myristic	C14:0	6.68 ± 0.51	7.08 ± 0.29	NS
Pentadecanoic	C15:0	0.54 ± 0.04	0.60 ± 0.02	NS
Palmitic	C16:0	24.93 ± 1.1	23.97 ± 0.60	NS
Heptadecanoic	C17:0	1.10 ± 0.07	1.16 ± 0.05	NS
Stearic	C18:0	14.43 ± 0.58	13.73 ± 0.14	NS
Arachidic	C20:0	0.24 ± 0.01	0.22 ± 0.01	NS
Behenic	C22:0	0.13 ± 0.01	0.11 ± 0.01	NS
Tricosanoic	C23:0	0.02 ± 0.00	0.02 ± 0.00	NS
Lignoceric	C24:0	0.06 ± 0.01	0.05 ± 0.01	NS
Myristoleic	C14:1	0.22 ± 0.02	0.25 ± 0.01	NS
Palmitoleic	C16:1	1.84 ± 0.11	2.07 ± 0.07	NS
Heptadecanoic	C17:1	0.62 ± 0.03	0.67 ± 0.05	NS
Eladic	C18:1n9t	1.80 ± 0.08	2.05 ± 0.31	NS
Oleic	C18:1n9c	37.10 ± 0.73	37.59 ± 1.13	NS
Eicosenoic	C20:1	0.12 ± 0.01	0.12 ± 0.00	NS
Linoleic	C18:2n6	3.85 ± 0.26	3.18 ± 0.25	NS
γ-Linolenic	C18:3n6	0.08 ± 0.00	0.06 ± 0.00	*
α-Linolenic	C18:3n3	0.79 ± 0.04	0.67 ± 0.04	NS
Eicosadienonic	C20:2	0.05 ± 0.01	0.06 ± 0.00	NS
Eicosatrienoic	C20:3n6	0.18 ± 0.02	0.15 ± 0.02	NS
Eicosatrienoic	C20:3n3	0.06 ± 0.01	0.06 ± 0.01	NS
Arachidonic	C20:4n6	1.55 ± 0.22	1.21 ± 0.15	NS
Eicosapentaenoic	C20:5n3	0.38 ± 0.06	0.27 ± 0.04	NS
Docosapentaenoic	C22:5n3	0.56 ± 0.06	0.05 ± 0.06	NS
Docosahexaenoic	C22:6n3	0.40 ± 0.04	0.42 ± 0.05	NS

The effect of sex on kidney knob fat depot fatty acid composition in Pag sheep lambs is presented in Table 4. Although some differences in myristic (C14:0), palmitic (C16:0), stearic (C18:0), oleic (C18:1n9c), and linoleic (C18:2n6) fatty acid proportions between ewe and ram lambs were observed, they were not statistically significant.

Table 3. Effect of sex on aggregate fatty acid profile of longissimus dorsi muscle intramuscular fat of Pag sheep lambs

Fatty acid	Sex		Level of significance
	Male	Female	
SFA	48.99 ± 1.10	49.42 ± 0.86	NS
MUFA	41.68 ± 0.71	42.74 ± 1.13	NS
PUFA	8.63 ± 0.62	7.17 ± 0.59	NS
UFA	50.31 ± 1.09	49.91 ± 0.85	NS
PUFA/SFA	0.18 ± 0.02	0.15 ± 0.01	NS
UFA/SFA	1.03 ± 0.04	1.10 ± 0.04	NS
n3	2.92 ± 0.18	2.51 ± 0.19	NS
n6	5.65 ± 0.47	4.61 ± 0.42	NS
n6/n3 ratio	1.93 ± 0.12	1.83 ± 0.08	NS

SFA-saturated fatty acids; MUFA-monounsaureted fatty acids; PUFA-polyunsaturated fatty acids; UFA-unsaturated fatty acids

Table 4. Effect of sex on fatty acid composition of kidney knob fat of Pag sheep lambs

Fatty acid		Sex		Level of significance
Name	Symbol	Male	Female	
Capric	C10:0	0.24 ± 0.03	0.35 ± 0.07	NS
Lauric	C12:0	0.54 ± 0.05	0.66 ± 0.14	NS
Trideccanoic	C13:0	0.04 ± 0.01	0.05 ± 0.02	NS
Myristic	C14:0	5.81 ± 0.33	6.22 ± 0.77	NS
Pentadecanoic	C15:0	0.44 ± 0.03	0.46 ± 0.03	NS
Palmitic	C16:0	20.28 ± 1.39	21.28 ± 1.41	NS
Heptadecanoic	C17:0	0.48 ± 0.02	0.50 ± 0.04	NS
Stearic	C18:0	23.64 ± 1.21	22.18 ± 0.63	NS
Arachidic	C20:0	0.28 ± 0.04	0.26 ± 0.07	NS
Behenic	C22:0	0.04 ± 0.01	0.03 ± 0.01	NS
Myristoleic	C14:1	0.42 ± 0.03	0.44 ± 0.02	NS
Palmitoleic	C16:1	3.69 ± 0.13	3.72 ± 0.10	NS
Oleic	C18:1n9c	38.73 ± 1.18	37.77 ± 1.83	NS
Eicosenoic	C20:1	0.18 ± 0.02	0.20 ± 0.06	NS
Linoleic	C18:2n6	2.90 ± 0.13	3.34 ± 0.21	NS
α-Linolenic	C18:3n3	1.20 ± 0.04	1.20 ± 0.19	NS
Eicosadienonic	C20:2n6	0.05 ± 0.01	0.14 ± 0.06	NS
Eicosatrienoic	C20:3n3	0.13 ± 0.04	0.10 ± 0.02	NS
Arachidonic	C20:4n6	0.04 ± 0.01	0.04 ± 0.01	NS

Table 5 presents the aggregate values of of SFA, MUFA, PUFA, UFA, *n*-3, and *n*-6 and ratios between PUFA/SFA, UFA/SFA and *n*-6/*n*-3 fatty acids from Pag sheep lamb kidney knob fat. Slightly higher values of SFA, PUFA and *n*-6, and higher ratios of PUFA/SFA and *n*-6/*n*-3 fatty acids were found in female lambs, while male lambs had higher values of MUFA, UFA and *n*-3, as well as a higher ratio of UFA/SFA.

Table 5. Effect of sex on aggregate fatty acid profile of kidney knob fat of Pag sheep lambs

	Sex		
Fatty acid	Male	Female	Level of significance
SFA	51.78 ± 1.06	51.98 ± 1.87	NS
MUFA	43.03 ± 1.15	42.14 ± 1.93	NS
PUFA	4.31 ± 0.18	4.79 ± 0.30	NS
UFA	47.34 ± 1.09	46.93 ± 1.86	NS
PUFA/SFA	0.08 ± 0.00	0.09 ± 0.01	NS
UFA/SFA	0.92 ± 0.04	0.91 ± 0.07	NS
n3	1.33 ± 0.05	1.29 ± 0.21	NS
n6	2.98 ± 0.14	3.50 ± 0.25	NS
n6/n3 ratio	2.24 ± 0.05	3.00 ± 0.55	NS

SFA-saturated fatty acids; MUFA-monounsaureted fatty acids; PUFA-polyunsaturated fatty acids; UFA-unsaturated fatty acids

Discussion

The present study was conducted to evaluate the effect of sex on the chemical composition and fatty acid profile of the longissimus dorsi muscle and kidney knob fat of Pag sheep lambs. In previous years many research papers on the topic of the carcass traits of Croatian indigenous breeds of lambs were published without mentioning the chemical composition and fatty acid profile of lamb meat.

The slaughter weight and carcass weight of experimental lambs from our study are in agreement with previous studies for the same breed (MIOČ et al., 2012; VNUČEC et al., 2014). The investigated Pag sheep lambs, according to EU Mediterranean classification system based on carcass weight (RUSSO et al., 2003), can be classified in category A: ≤ 7.0 kg. The values of the basic chemical components of the MLD suggest that Pag sheep lambs had a higher percentage of dry matter, fat, and ash, but a lower percentage of proteins compared to Lacha, Rasa Aragonesa and Apenninica suckling lambs (BERIAIN et al., 2000; RUSSO et al., 2003). The very high percentage of fat in Pag sheep lambs MLD (5.25-5.93 %) may be the result of the high percentage of fat in Pag sheep milk (7.47-8.02 %; ANTUNAC et al., 2011).

The majority of fatty acids of the MLD in the present study were palmitic (C16:0), stearic (C18:0) and oleic (C18:1), as also reported by VELASCO et al. (2004). The same authors also found a significantly higher percentage of myristic (C14:0) and palmitic (C16:0) acids in unweaned compared to weaned Talaverana breed lambs. The higher proportions of those fatty acids in unweaned lambs were the result of the greater proportion of those fatty acids in the sheep milk fat and the length of lactation. A similar fatty acid composition as that found in Pag sheep lambs was reported for Altamurana and Trimeticco suckling lambs (MARINO et al., 2008), except eicosenoic (C20:1), arachidonic (C20:4n6), eicosapentaenoic (C20:5n3), and docosahexaenoic (C22:6n3) fatty acids, which were of higher proportions. The Pag sheep lamb MLD had higher proportions of oleic (C18:1n9c), α-linolenic (C18:3n3), eicosapentaenoic (C20:5n3; EPA), docosapentaenoic (C22:5n3; DPA), and docosahexaenoic (C22:6n3; DHA) fatty acids than the meat of some Spanish and Italian lambs of similar age and slaughter weight (LANZA et al., 2006; OSORIO et al., 2007; VACCA et al., 2008; JUÁREZ et al., 2009).

The determined values of SFA in the MLD are similar, while values of PUFA, *n*-3 and *n*-6/*n*-3 ratio of fatty acids are lower in Pag sheep lambs compared to those observed by MARINO et al. (2008) in Altamurana and Trimeticcio lambs of similar age, fed mainly with maternal milk. Similar values of SFA, MUFA, PUFA, and UFA/SFA were reported by BERIAIN et al. (2000) for Lacha and Rasa Aragonesa suckling lambs, and JUÁREZ et al. (2008) for the lambs of five Spanish sheep breeds. The higher proportion of UFA compared to SFA in Pag sheep lambs increases the potential for oxidation, which influences the shelf-life of the meat (TSHABALALA et. al., 2003). The PUFA/SFA ratio in Pag sheep lambs was lower than in Altamurana and Trimeticco lambs (MARINO et al., 2008). Differences in fatty acid composition in the sheep lamb breeds compared may be explained by differences in production systems. The production system represents the combined effects of breed, weight, diet, sex, age and husbandry, all of which may affect meat fatty acid composition (DÍAZ et al., 2005).

The most common fatty acids in Pag sheep lambs' kidney knob fat were: oleic (C18:1n9c), stearic (C18:0), palmitic (C16:0), myristic (C14:0), palmitoleic (C16:1), linoleic (C18:2n6), and α-linolenic (C18:3n3), which is in agreement with BERIAIN et al. (2000) and OSORIO et al. (2007). Pag sheep lambs had higher proportions of α-linolenic, linoleic, palmitoleic, and stearic fatty acids, but lower proportions of myristic, palmitic, and oleic fatty acids compared to Lacha and Rasa Aragonesa suckling lambs' subcutaneous adipose tissue (BERIAIN et al., 2000). Breed type has a great influence on the proportions of individual fatty acids (C12:0, C14:0 and C18:2 isomers), due to the differences in the ewes' milk production (JUÁREZ et al., 2008).

Comparing aggregate values of fatty acids from the MLD and kidney knob fat of Pag sheep lambs, we determined higher values of SFA, MUFA and *n*-6/*n*-3 ratio in

kidney knob fat, while the percentages of PUFA, UFA, PUFA/UFA ratio, and UFA/SFA ratio were higher in the MLD. BERIAIN et al. (2000) determined a higher percentage of MUFA and UFA/SFA ratio but a lower percentage of SFA and PUFA of the i.m. fat of the longissimus muscle of Lacha and Rasa Aragonesa suckling lambs compered to Pag sheep lambs. Comparison of the obtained results with those from the literature is very difficult because the fatty acid composition of lamb fat depots is affected by the length of lactation and the feed consumed (VELASCO et al., 2004).

Conclusions

The chemical composition of the longissimus dorsi muscle and fatty acid composition of MLD intramuscular fat and kidney knob fat from Pag sheep lambs were revealed by this study. As is evident from the results shown, there is no statistically significant effect of sex on the chemical composition and fatty acid profile of the MLD muscle and kidney knob fat of Pag sheep lambs. Comparing the obtained results for Pag sheep lambs' fatty acid profile with those available in the literature, we can conclude that the fatty acid profile in suckling lambs of different sheep breeds is very similar. This similarity is most probably a consequence of the similar fatty acid profiles of maternal milk, which is the main food of suckling lambs.

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SAŽETAK

Cilj ovog rada je bio analizirati kemijski sastav musculus longissimus dorsi (MLD), sastav masnih kiselina MLD-a i bubrežnog loja trupova sisajuće paške janjadi te utvrditi utjecaj spola na navedene pokazatelje. Iako paška ovca pripada skupini ovaca kombiniranih proizvodnih svojstava, primarno je uzgajana za proizvodnju mlijeka, dok je meso drugi važan izvor prihoda. Za ovo istraživanje uzeti su uzorci mišića i loja s ukupno 12 trupova (6 muške i 6 ženske) paške janjadi zaklane pri prosječnoj dobi od 33 dana. Iako je ženska janjad imala veću tjelesnu masu prije klanja, trupovi muške janjadi bili su prosječno znatno teži ($P<0,05$). Kemijski sastav MLD-a nije bio pod utjecajem spola; meso muške i ženske janjadi sadržavalo je 25,82 % i 26,00 % suhe tvari, 74,18 % i 74,00 % vode, 19,37 % i 19,13 % proteina, 5,25 % i 5,93 % masti te 1,17 % i 1,15 % pepela. Štoviše, spol nije imao statistički značajan utjecaj na sastav masnih kiselina MLD-a i bubrežnog loja trupova paške janjadi. Međutim, bubrežni loj istraživane janjadi sadržavao je više zasićenih masnih kiselina od mišićnog tkiva, dok je sadržaj dugolančanih polinezasićenih masnih kiselina bubrežnog loja bio niži od onog u MLD-u. Ukupni sadržaj zasićenih, mononezasićenih i polinezasićenih masnih kiselina u MLD-u paške janjadi u skladu je s rezultatima drugih autora za jestive dijelove trupa sisajuće janjadi mediteranskih pasmina zaklane u dobi od 25 do 45 dana.

Ključne riječi: paška janjad, musculus longissimus dorsi, bubrežni loj, kemijski sastav, masne kiseline